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Direct Physicochemical Treatment with Ozone

Research Report No. 32

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ch Program for the Abatement of Municipal Pollution
nder Provisions of the Canada-Ontario Agreement
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DIRECT PHYSICOCHEMICAL TREATMENT WITH OZONE

by

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RESEARCH PROGRAM FOR THE ABATEMENT
OF MUNICIPAL POLLUTION WITHIN THE
PROVISIONS OF THE CANADA-ONTARIO
AGREEMENT ON GREAT LAKES WATER QUALITY

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ABSTRACT

A pilot study of direct physicochemical treatment of wastewaters using ozone is described. The pilot plant consisted of three principal elements: a chemical clarification unit, an ozone contact section, and a dual media filter. The chemical clarification unit removed up to 95% of the suspended solids in the raw sewage feed. The ozone contact section consisted of four spray contactors. These were generally sufficient to reduce the soluble BOD_5 by 40%. The filter served to polish the effluent by removing the last traces of suspended solids.

The amount of ozone needed to reduce the BOD_5 and the TOD in the effluent of a chemical clarification unit to acceptable levels has been studied. The amount was found to depend principally on the initial TOD and to be a weaker function of other variables. The stoichiometric efficiency of ozone was increased by providing holding time between contactors.

It was demonstrated that treatment with eight ozone contact stages resulted in an effluent with a BOD_5 of 16 mg/l.

A comparative economic study was made of direct physicochemical treatment with activated carbon. The cost of the ozone process was 17% higher. However, credit was not allowed for the disinfection and aeration which occurred during ozonation.

RÉSUMÉ

Le but de cette étude est d'étudier l'efficacité d'un traitement physicochimique à l'ozone. L'installation pilote est constituée de trois éléments principaux, une unité de coagulation chimique, une section pour le traitement à l'ozone et un filtre à lit double.

L'unité de précipitation chimique enlève jusqu'à 95% des solides en suspension de l'alimentation. La section du traitement à l'ozone est constituée de quatre (4) colonnes de contact où l'eau est pulvérisée dans une atmosphère d'ozone et d'oxygène. C'est généralement suffisant pour réduire la DBO_5 soluble de 40%. Le filtre enlève les solides en suspension non enlevès par la précipitation et aussi ceux formés durant l'ozonation.

La quantité d'ozone nécessaire pour diminuer la DBO_5 et la DTO à un niveau acceptable dans l'effluent de l'unité de précipitation chimique a été étudiée soigneusement. Cette quantité dépend principalement de la DTO initiale et à un niveau moindre, de d'autres variables. Le temps de rétention entre chaque étapes augmente la quantité d'ozone absorbé et, par conséquent, l'efficacité du procédé. Il est démontré qu'on peut obtenir une eau d'une bonne qualité avec un système qui comprendrait huit étapes d'ozonation.

Une étude écomonique comparative a été réalisée entre un traitement physicochimique à l'ozone et un traitement physicochimique au charbon activé. Le coût du procédé avec de l'ozone est de 17% plus élevé. Toutefois, on ne tient pas compte dans cette comparaison de la désinfection et de l'aération supplémentaire dues à l'ozone.

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CONCLUSIONS

The following conclusions were reached on the basis of the results of this study:

1. Ozone treatment of wastewater can play a role equivalent to activated carbon in direct wastewater treatment.

2. The use of ozone instead of activated carbon does not significantly affect the annual costs, yet there are substantial benefits. The effluent wastewater contains more dissolved oxygen than is required to eliminate its BOD.

3. Suspended solids increase as ozonation occurs.

4. Ozone's ability to oxidize organic material is greater than that indicated by stoichiometry when the organic material is in high concentration.

5. The amount of TOD removed per pound of ozone decreases as the inlet TOD decreases.

6. Between 75 and 90 percent of phosphates is removed in the coagulation flocculation sedimentation basin.

7. The fraction of ozone absorbed by the wastewater in each stage of the ozonation unit is increased by providing detention time between stages. The detention time does not change the amount of TOD removed by ozone.

8. The nitrogenous compounds in wastewater are not significantly affected by ozonation. The rate of oxidation of ammonia nitrogen is increased by increasing the pH but is still not fast enough to be an economical means of eliminating nitrogenous oxygen demand.

9. The BOD_5 was reduced to 16 mg/l from 62 mg/l when ozonation was performed in eight contact stages.

10. Ozonation tends to neutralize the pH, regardless of the starting value.

RECOMMENDATIONS

It is recommended that the development of ozonation as a wastewater treatment process be continued at a pace equal to that of adsorption on activated carbon. Particular stress is needed in the following areas:

1. Elucidation of the role of surface phenomena at the interface between ozone-rich gas and wastewater.

2. Comparison of the use of various types of mass transfer equipment and enunciation of principles on which a complete design can be based.

3. Research to improve the thermodynamic efficiency of ozone generators.

1. INTRODUCTION

1.1 Physicochemical Treatment

Direct physicochemical treatment of wastewater is any treatment scheme which depends on chemical and physical processes. Processes which can be included in a direct physicochemical treatment scheme are chemical precipitation, carbon adsorption, ozonation, breakpoint chlorination, reverse osmosis, ion exchange, single media and multimedia filtration, and ammonia stripping. It would be bizarre to find all of the above processes in the same treatment scheme but if the effluent requirements are high many of them may be employed.

Physicochemical treatment is not generally a first choice. If effluent standards are not too severe and there are no unusual restrictions, biological treatment will be much more economical. But when such things as very high effluent standards, limited space, high proportions of industrial waste, necessity to eliminate heavy metal or pesticides from effluent, high colour, highly variable flow rate or highly variable waste concentration are important considerations, direct physicochemical treatment is an important alternative. For these cases, direct physicochemical treatment will often be less costly than biological treatment followed by tertiary treatment processes.

Biological treatment schemes can be operated very successfully under stable conditions. Although there are a few conditions which might make biological treatment impossible, the microorganisms have an amazing ability to adapt to possibly toxic conditions. But if certain chemicals are added suddenly to the influent of a biological treatment process, the microorganisms can be temporarily inactivated. Poor effluent will be produced for a long period afterwards. Physicochemical processes have a much larger tolerance for changes in the chemical nature of influent wastewaters.

The same phenomenon can occur when sudden changes are made in other operating variables. For example, shock loads and sudden increases in the flow rate or in the oxygen demand of the wastewater are very damaging to biological treatment schemes. Physicochemical treatments are more tolerant of these changes.

Physicochemical treatment processes are more tolerant of cold weather and sudden changes of temperature than are biological treatment processes. This is an important plus in the Canadian climate.

The two essential steps in direct physicochemical treatment are the removal of insoluble and soluble pollutants. The removal of insoluble pollutants of colloidal or larger sizes is done in a chemical precipitation unit. The chemical precipitation unit performs three separate functions: coagulation, flocculation and sedimentation. Coagulation is generally performed with ferric chloride ($FeCl_3$), alum ($Al_2(SO_4)_3$), or lime ($Ca(OH)_2$). These chemicals reduce the negative electrostatic potential between particles and permit them to be flocculated. The coagulation chemicals are generally added in a rapid mix tank which may be a separate unit or a part of one large unit called a clarifier.

Much more gentle agitation is used to flocculate the wastewater. The gentle agitation causes particles of similar electrostatic charge to strike one another and stick together. The growth of agglomerated particles is continued until sedimentation becomes possible.

Sedimentation occurs in a unit without any agitation. The particles which have been grown in the flocculation process are now allowed to settle under gravity. Designs of sedimentation basins can vary widely and the choice of the most cost effective design is an important part of a treatment plant designer's task.

1.2 Direct Physicochemical Treatment of Wastewater with Activated Charcoal

The effluent of the chemical precipitation unit generally has a very low suspended solids content, under 10 mg/l. Most of the oxygen demand remaining is soluble and the most cost effective physicochemical way to eliminate it is adsorption on activated carbon.

Adsorption of pollutants on activated carbon can be carried out in a number of different ways. Powdered activated carbon (PAC) has been widely used in potable water treatment. Generally, powdered activated charcoal is added in a mixing tank and removed in a sand filter. Powdered activated charcoal is slightly cheaper than granular activated carbon, but can be used only once and then must be discarded. The treatment of wastewater with PAC has received only slight consideration.

Granular activated carbon (GAC) is the material of first choice for adsorption of soluble organic pollution. Its most important advantage is that it can be regenerated, which generally compensates for its higher cost per pound. Granular activated carbon is packed in more than one column. The columns can be used in different sequences so as to be able to take maximum advantage of the activated carbon's adsorptive capacity. Columns can be of two general types, upflow or downflow. It is not yet clear which type of operation is the better.

Figure 1 shows the flowsheet for a typical direct physicochemical wastewater treatment plant (Weber, 1972).

1.3 Direct Physicochemical Treatment of Wastewater with Ozone

Ozone has for many years been used to solve odour and colour problems, and to disinfect potable water supplies. It has the ability to oxidize the organic pollution in wastewater but the costs are expected to be high.

Recent studies by Airco (Huibers *et al*, 1969; Wynn *et al*, 1973) demonstrated that the COD of secondary effluents could be reduced substantially with ozone. They treated a variety of different wastewaters which were mostly of the type called secondary effluents. In the more recent study (Wynn, 1973), between 50% and 80% of influent COD was eliminated. The COD's of most of the wastewaters treated were quite low and little was said about treating wastewaters with higher COD concentration.

Hewes (1971) conducted considerable theoretical work on the rate constants and mechanism of ozone's oxidation of COD. All of his data suggested that the rate of reaction between ozone and organic pollutants of secondary effluents could be described by a power law with the reaction rate being first order in the ozone concentration and the COD. He suggested that the ozone's decomposition created free radicals and that the concentration of free radicals thus created determined the rate at which COD was eliminated.

Previous work showed that ozonation produced additional suspended solids. If this effect could be confirmed it would demonstrate a mechanism by which ozone might have a greater effectiveness than simple stoichiometry indicates.

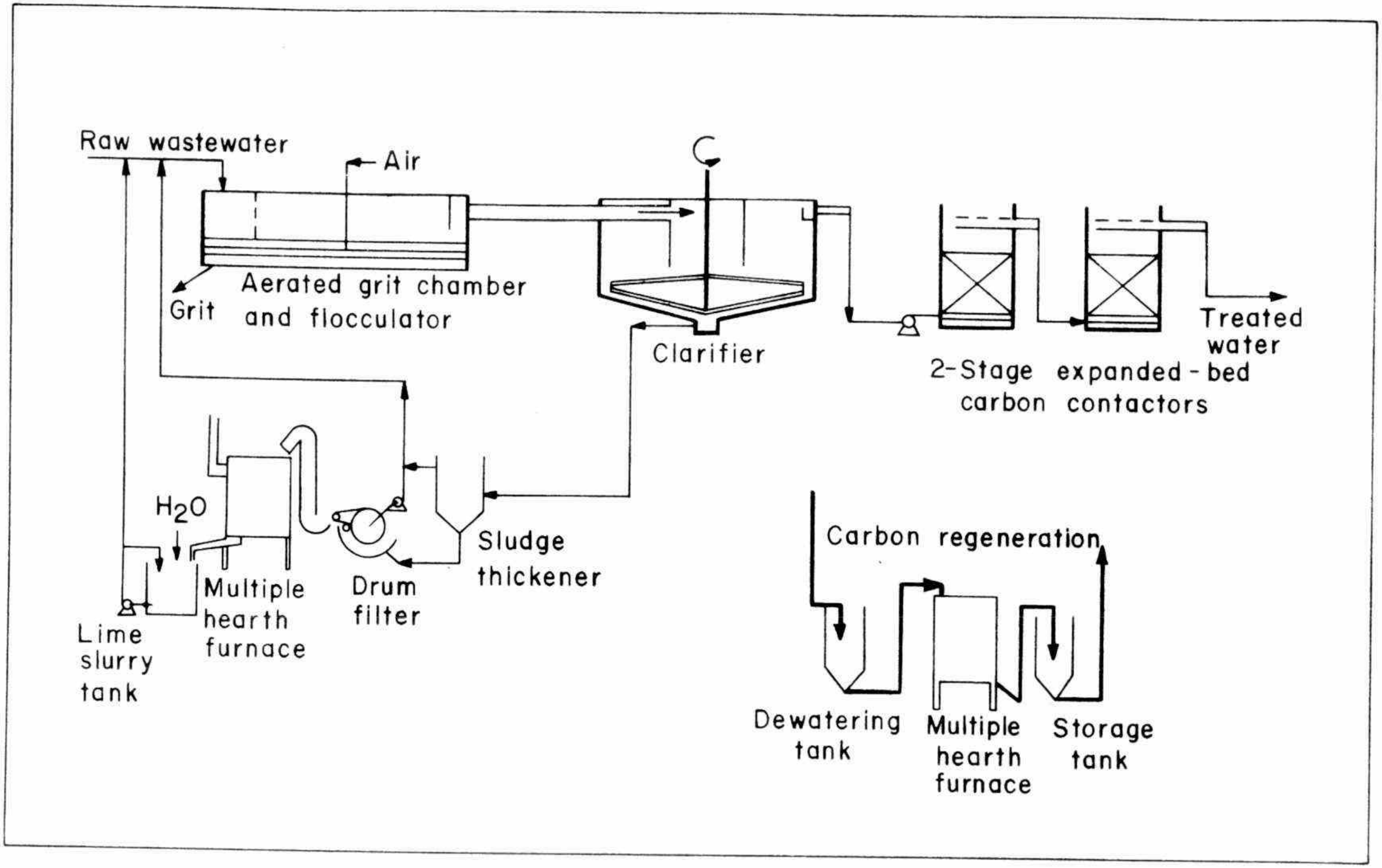

FIGURE I. TYPICAL FLOWSHEET FOR TREATMENT OF WASTEWATER BY CHEMICAL CLARIFICATION AND ADSORPTION (WEBER, 1972).

1.4 Objectives of this Study

In this study the ultimate aim was to determine whether ozonation could be combined with chemical clarification and sand filtration to completely treat wastewater. In other words, could ozonation be used in place of activated carbon adsorption to remove the soluble oxygen demand?

At the same time, the effect of ozonation on the suspended solids in wastewater was investigated. If ozonation increased suspended solids, ozone could be used much more effectively.

2. EXPERIMENTAL EQUIPMENT AND PROCEDURES

2.1 Wastewater Treated

The wastewater treated in this study was raw sewage from the Centre Hospitalier Universitaire (CHU) of the Université de Sherbrooke. The CHU is the medical teaching and medical research wing of the university in addition to being a regional hospital for the Eastern Townships.

In general, the raw sewage from the hospital has the characteristics of a sanitary sewage of domestic origin. Most of the wastewater is from the laundry and the kitchens in addition to the normal sources. Because of the research activity at the CHU, the sewage contains an unusually wide range of organic and inorganic chemicals.

The CHU treats its own wastewater with an activated sludge process. The secondary effluent could, therefore, be used in our pilot plant study. Such tests will be made shortly but are not included in this report. Generally, the raw sewage for this study was taken at the inlet of the waste treatment plant and trucked to the university.

2.2 The Pilot Plant

The pilot plant used during this study was principally composed of: a chemical clarification unit; an ozonation unit; and a dual media filter. The plant was designed for direct physicochemical treatment and was, consequently, able to accept influents with a high TOD. The equipment was, therefore, different from other pilot installations where ozonation has been used as a tertiary treatment. Generally, the flow rate used was three US gpm but the capacity of the pilot plant was six US gpm.

Figure 2 is a flowsheet of the chemical precipitation unit. The wastewater was stored in six stirred reservoirs with a total capacity of 3000 US gallons. Feed from these reservoirs was withdrawn by a Moyno pump and sent to the rapid mix tank. The feed rate to the rapid mix tank was controlled by adjusting the variable speed drive on the Moyno pump while measuring the speed of rotation with a Strobotac. The use of rotameters was thus avoided. Rotameters were used in the early phases of this study but often blocked with suspended material.

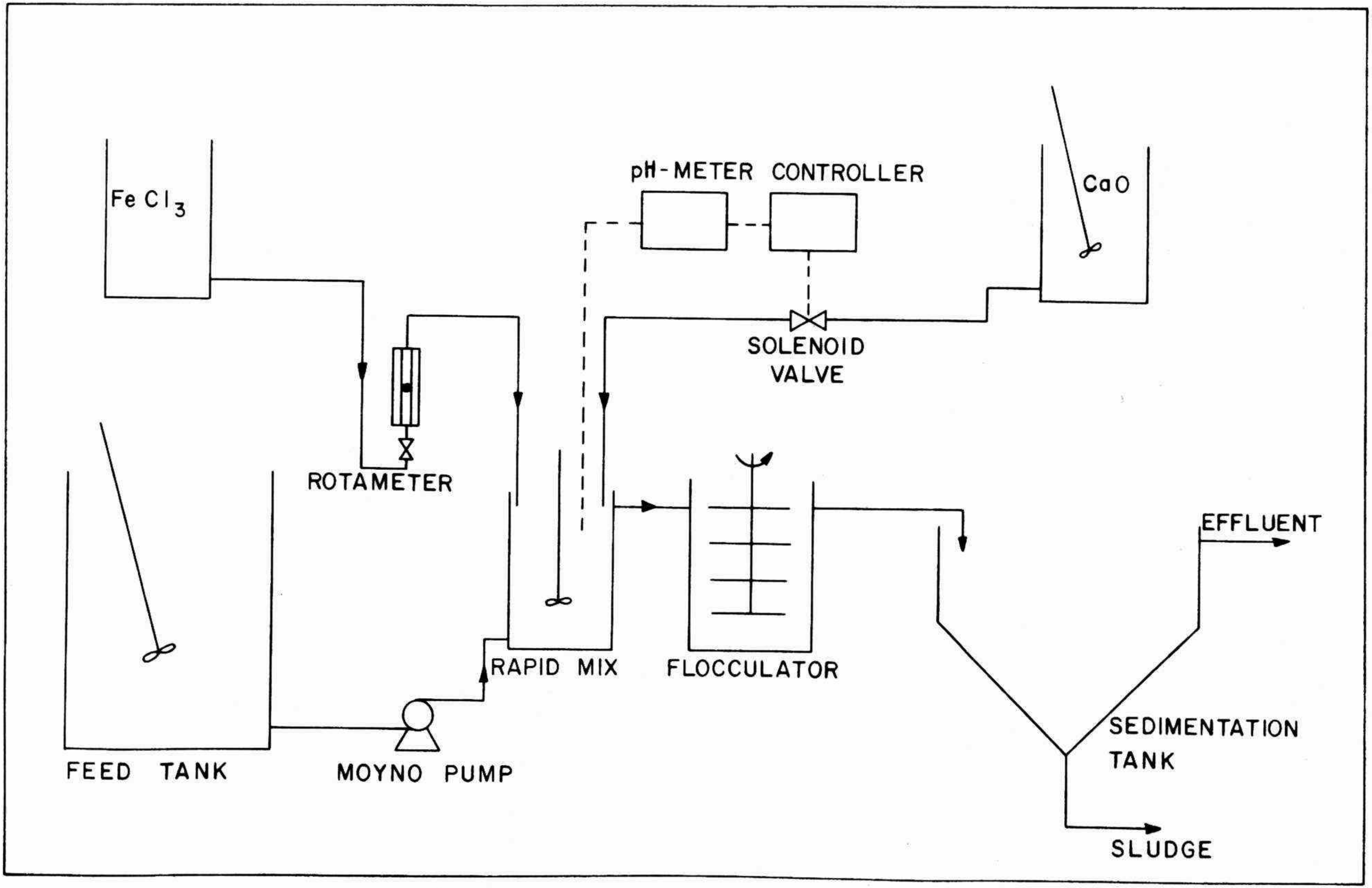

FIGURE 2 CHEMICAL PRECIPITATION UNIT.

In the rapid mix tank the pH was controlled by an automatic controller. Lime slurry was added on the command of this controller so as to keep the influent pH level at a predetermined value. Flocculation was made to occur in a separate tank which followed the rapid mix tank. Finally, the wastewater was sent to a sedimentation basin.

Figure 3 is a flowsheet of the ozone treatment section of the pilot plant. The wastewater was pumped in sequence through nozzles into each of four ozone contact stages. This contact between small droplets of water and ozone in an ozone-oxygen atmosphere was very intimate. The flow rate through the first nozzle was the flow rate through the entire plant, i.e. very often three US gpm. However, in the subsequent ozone chambers the wastewater was pumped, on an average, twice through each nozzle.

Retention vessels were installed between each ozone contact chamber about halfway through the investigation because it was believed that this prolonged storage would increase the ozone efficiency. They were designed to be of variable capacity with a maximum of 60 US gallons.

Ozone was produced using oxygen. The ozone was produced in tube ozonators, manufactured by Canatraco. The nominal capacity of the ozone generator was 40 grams per hour from oxygen.

The ozone generator was really two ozone generators. One had two electrodes while the other had three. Each electrode had a nominal capacity of eight grams per hour for producing ozone from oxygen. The rate of ozone production was varied by adjusting the voltage, the oxygen flow rate or by using various numbers of electrodes. The ozone concentration in oxygen was in the range of 20-30 mg/l. This corresponds to a range of concentration of from 1.4% to 2%.

The ozone-oxygen mixture stream was then divided into four equal streams by rotameters and valves and then routed to each of the gas-liquid contactors. The outlet stream from each of the contactors was vented outside. Sampling points were available for measuring the ozone concentration at the outlet of the generator and the outlets of each of the contact chambers. Figure 3 clarifies the verbal description. given above.

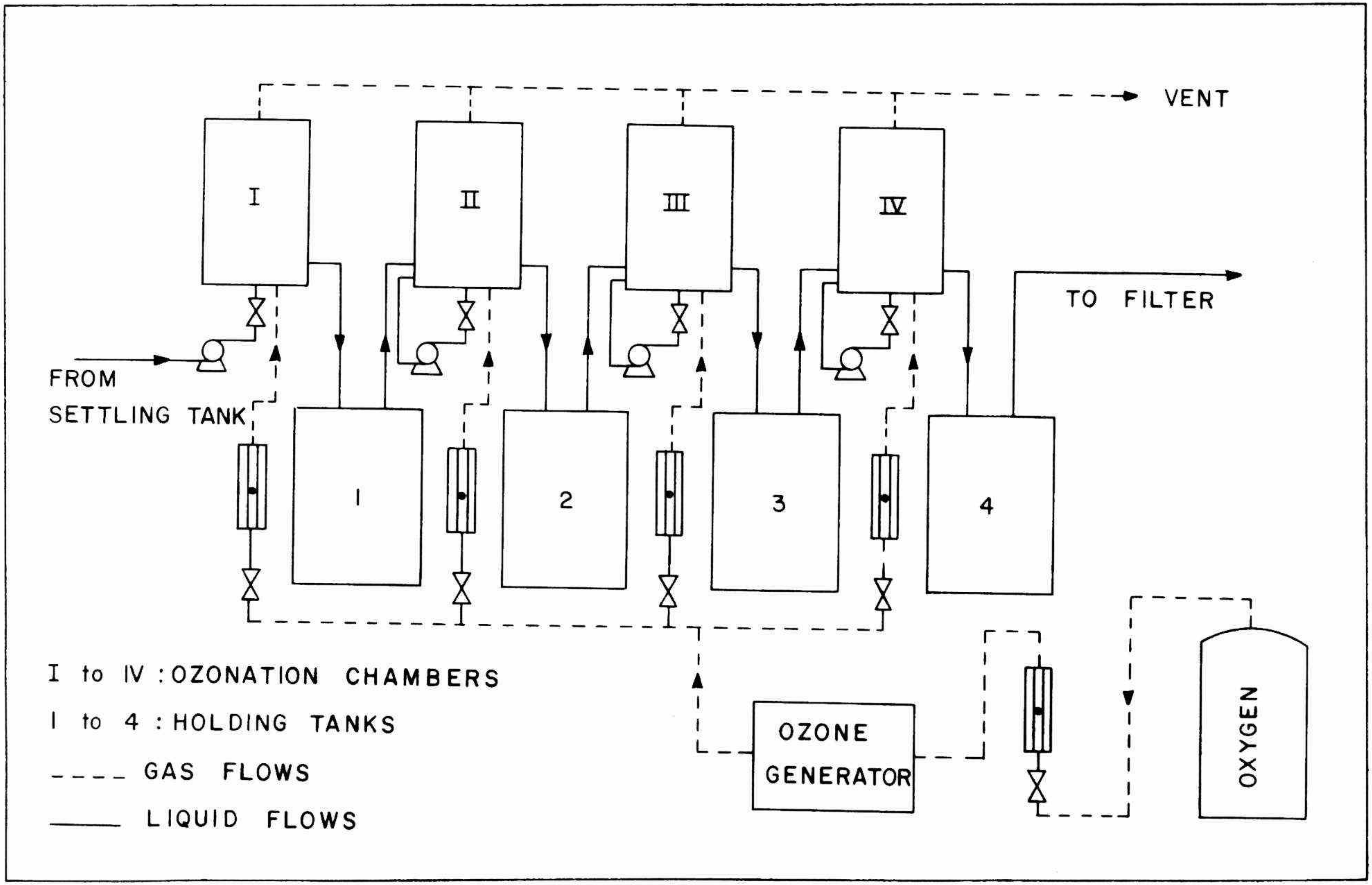

FIGURE 3 OZONATION PILOT PLANT.

All the gas piping used was 316 stainless steel. The contact vessels were made of glass-lined steel. Most of the other equipment was mild steel painted with epoxy paint. None of the equipment showed any corrosion during the period of experimentation. The wastewater piping was made from ordinary steel pipe and was a little corroded by the dissolved ozone in the water.

2.3 Experimental Procedures

2.3.1 Operation of pilot plant

The reservoirs were first filled with the wastewater from the CHU. The mixers were turned on so as to prevent settling in these vessels and to homogenize the contents.

The various pumps as shown in Figures 2 and 3 were started and adjusted. The pH controller was set and turned on. Most of the other operations in the pilot plant were controlled manually but the operation was very stable and presented no problems. The ozone dosage rate was adjusted manually by varying the oxygen flow rate and/or the number of electrodes in operation.

2.3.2 Sampling and analysis

There were sampling points for the wastewater at the outlets of the storage reservoir, the sedimentation basin, each of the four contact chambers and their intermediate storage reservoirs, and the dual media filter. The gas sampling points were at the outlet of the ozone generator and the outlets of each of the contact chambers.

For each run, the following operational parameters and sample analyses were recorded:

1. All the gaseous and liquid flow rates.
2. The ozone concentration in the gaseous effluent from the ozone generator and each of the contact chambers.
3. The pH and the concentration in mg/l of TOD, suspended solids, dissolved oxygen, dissolved ozone in wastewater streams between ozone contact stages.
4. The pH and the concentration in mg/l of BOD, TOD, dissolved oxygen, dissolved ozone, suspended solids, ortho and

total phosphates, ammonia, nitrates, nitrites and organic nitrogen in the feed, and in the effluent of the sedimentation basin, the final ozonation chamber and the filter.

An evacuated glass bulb of 2.1 litres capacity was used to take samples of the gas streams. The glass bulb could be connected to any of the sample points previously mentioned. The analysis for ozone was performed by the method described in Appendix II.

Wastewater samples were taken in four-litre bottles which had been washed with concentrated HCl solution and rinsed with distilled water. All analyses were made on the same day as the experimental run.

The samples for dissolved oxygen and dissolved ozone were taken separately and analysed within two minutes. All the analytical techniques are described in Appendix II.

3. RESULTS AND DISCUSSION OF RESULTS

3.1 Preliminary Experiments

3.1.1 Chemical precipitation

Initially, a number of runs were made to determine the best way of operating the chemical precipitation unit. Jar testing had shown that if the pH was not controlled, the amount of ferric chloride ($FeCl_3$) required for coagulation could vary between 30 and 50 mg of ferric ion (Fe^{+++}) per litre of wastewater. If the pH was first adjusted to 9.5 with lime before performing the coagulation, the amount of ferric chloride required was reduced and was not a function of the sample. Generally, the best coagulation was obtained with 20 mg of ferric ion per litre of water.

In Appendix III (Run No. 1), the results from a coagulation-sedimentation run are reported. Extremely stable operation was obtained. Over a nine-hour test, the value of inlet and outlet variables did not change significantly.

3.1.2 Ozonation

Earlier work had demonstrated that ozone has a significant effect on both TOD and suspended solids. It was found that ozone tended to increase the amount of suspended solids, but the effect was small. Ozonation also reduced the absolute value of the zeta potential of colloidal particles. This was in agreement with the results of other workers who suggested ozone could be used as a coagulant.

There was an indication that the increase in suspended solids was observable in the early pilot plant data. More experimentation was performed in this project which did indeed corroborate the earlier finding. This will be discussed later in the report.

To eliminate the possibility that spraying or aeration were causing effects observed later, blank runs were made with nitrogen and with oxygen without ozone, and compared to a run with oxygen and ozone. These runs demonstrated that the effects observed in later work were due to ozonation and not to aeration or stripping.

Figure 4 shows the suspended solids as the wastewater moved through the ozone contact chambers and the dual media filter for each

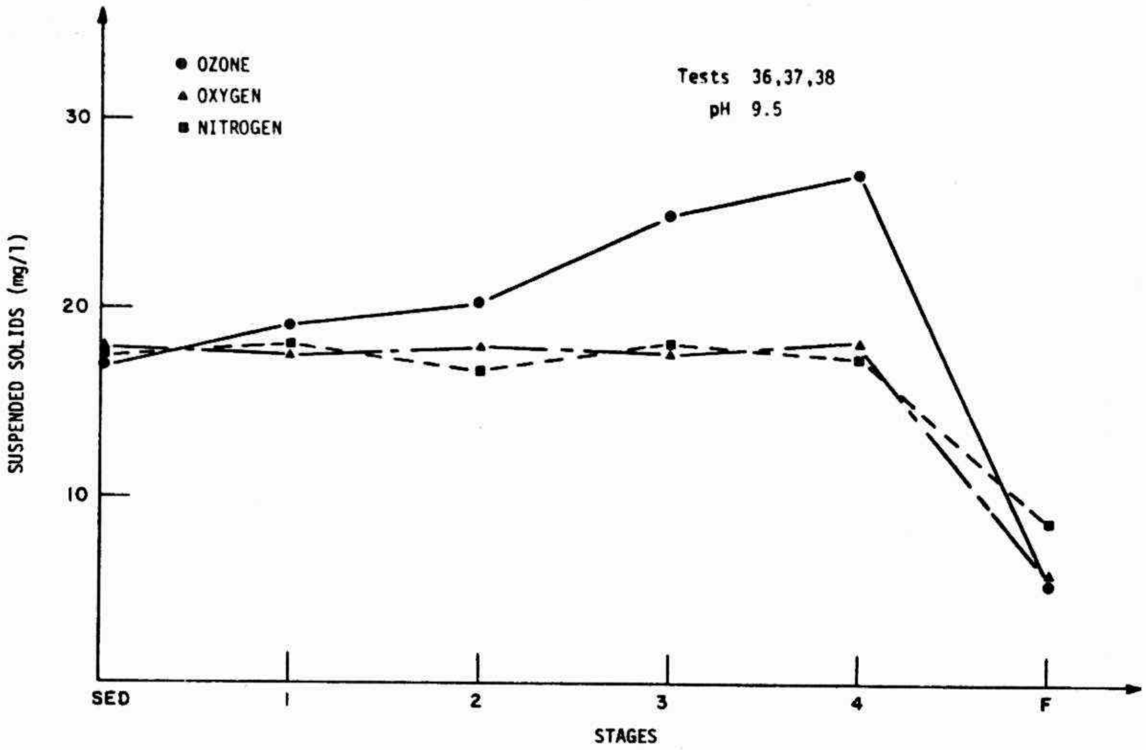

FIGURE 4 VARIATION OF SUSPENDED SOLIDS ACROSS PILOT PLANT DURING CONTROL EXPERIMENTS

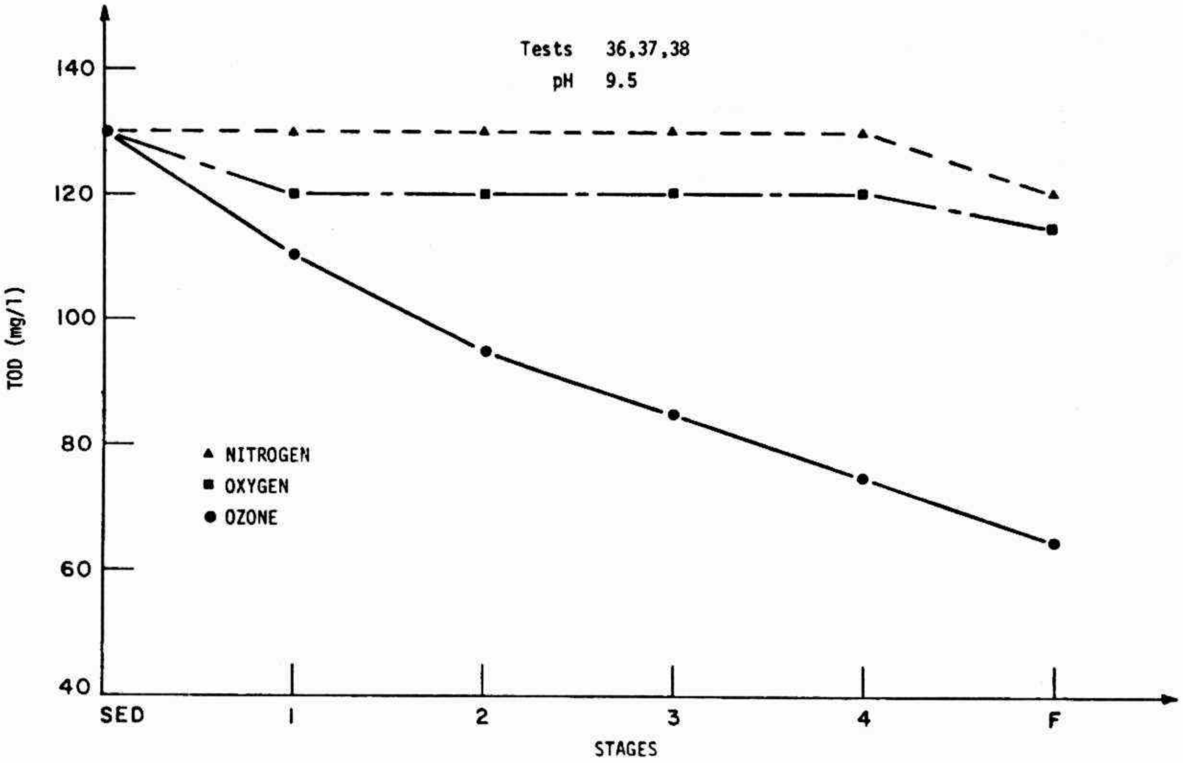

FIGURE 5 VARIATION OF TOD ACROSS PILOT PLANT DURING CONTROL EXPERIMENTS

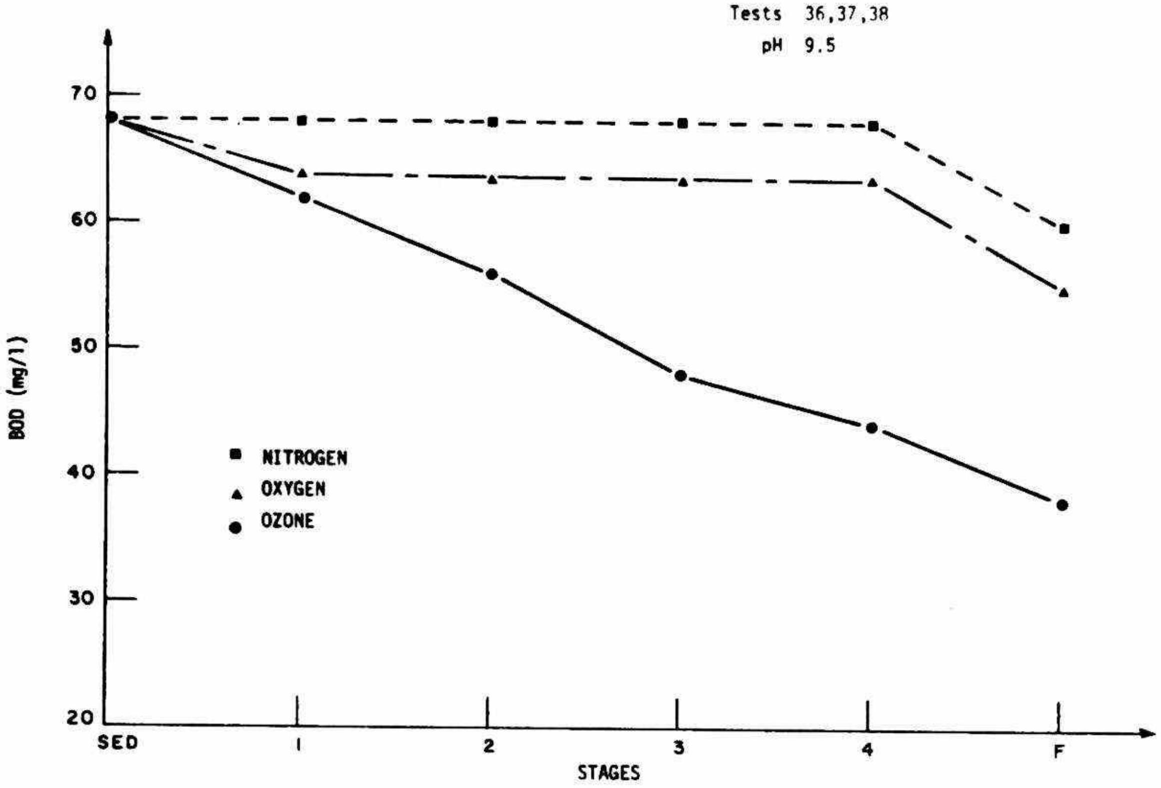

FIGURE 6 VARIATION OF BOD ACROSS PILOT PLANT DURING CONTROL EXPERIMENTS

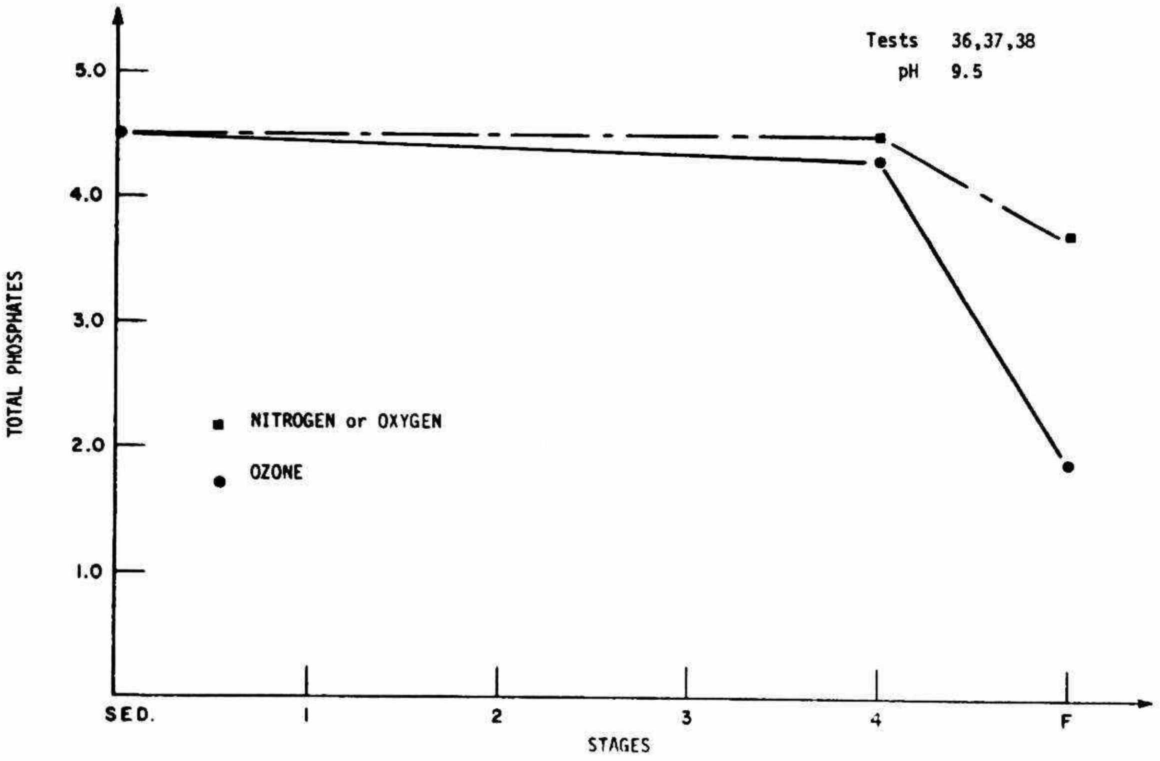

FIGURE 7 VARIATION OF TOTAL PHOSPHATES ACROSS PILOT PLANT DURING CONTROL EXPERIMENTS

of the three above described situations. The numbers on Figure 4 refer to the contact stages, SED refers to the sedimentation basin and F to the filter. When nitrogen or oxygen alone was passed through the gas contact chambers the suspended solids remained essentially constant until the filter. When ozone and oxygen were used in the gas contact chambers, there was a significant increase in the suspended solids content of the wastewater after each gas-liquid contact stage. Ozone had obviously precipitated soluble material. Finally, in the filter, a large portion of the suspended solids was removed.

For these same three runs, Figure 5 shows the variation of TOD across the pilot plant. Clearly nitrogen had no effect on the TOD. Oxygen seemed to reduce the TOD by a small amount, but the amount corresponded only to the oxygen dissolved in the wastewater. On the other hand, ozone and oxygen had a pronounced effect on the TOD content. The TOD declined continually across the ozone contact stages and the dual media filter. Figure 6 is similar to the curve for TOD and demonstrates that, at least qualitatively, TOD may be used interchangeably with BOD_5 for demonstrating the effects of ozone. Throughout the work, TOD's were relied upon and BOD_5's used occasionnally to confirm that the TOD variations applied to the BOD_5.

In Figure 7, the effect of ozone on the phosphates is examined. Clearly, none of nitrogen, oxygen, or oxygen and ozone mixtures had any effect on the total phosphates in the gas contact stages. In all cases some phosphates were removed in the filter but the amount was greatest when ozone was used. It is suspected that when suspended solids increase across the ozonation stages, the amount of soluble phosphates is reduced. The insoluble phosphates were susceptible to removal in the filter, while the soluble phosphates were not. This is discussed in greater detail in Section 3.5 of this report.

3.2 Total Oxygen Demand Reduction

3.2.1 Ozone's effect on organic material

The main object of this work was to establish to what extent ozonation can be used economically to reduce the oxygen demand of wastewater. As a start, a quick qualitative look at the action of ozone on

TOD is useful. Figure 5 in Section 3.1.2 includes some data of the type included in this section. Figures 8 and 9 show the variation of TOD and BOD_5 in the contact stages and the filter for two other runs. The graphs show clearly the reduction of oxygen demand in each stage.

Both of these graphs suggest that TOD dropped more in the early stages than in the later stages. The amount of ozone fed to each stage was equal. Perhaps ozone use efficiency was a function of initial TOD. Later this observation is examined more closely and is found correct.

3.2.2 Interstage storage

Many factors may affect the efficiency with which ozone is used. Among the most obvious is the possibility that by feeding too much ozone one attempts to oversaturate the wastewater. Of course this reasoning assumes that the oxidation of organic material occurs in the liquid phase and is slow compared to diffusion.

In the early part of the study, the ozone residual was high and it was believed that wastewater leaving the contact stages was saturated. It was difficult to be definite since Henry's law constant of ozone is very difficult to measure and has not been reliably reported. There was some concern that the water saturated with ozone could travel from one contact stage to the next without allowing sufficient time for the reaction to occur. Ozone utilisation based on mass balances for the gas stream was poor. Huibers et al (1969) had reported the need for interstage storage and this suggestion was tested.

The variable volume storage described in Section 2 was installed. The variation of percentage ozone consumed was measured as a function of the amount of storage between stages. This was done for the normal four stage contactor and a modification of the equipment i.e., the two stage contactor. The two stage contactor permitted greater interstage storage.

Data presented in Figure 10 demonstrate how ozone may be wasted. The more ozone fed, the lower was the amount absorbed into wastewater. The ozone absorbed into the wastewater was only known by using a mass balance. It is impossible to say with certainty what happens to the ozone which does not leave with the vented gas. One thing was certain: it had a greater chance of being effective than ozone which goes out the vent.

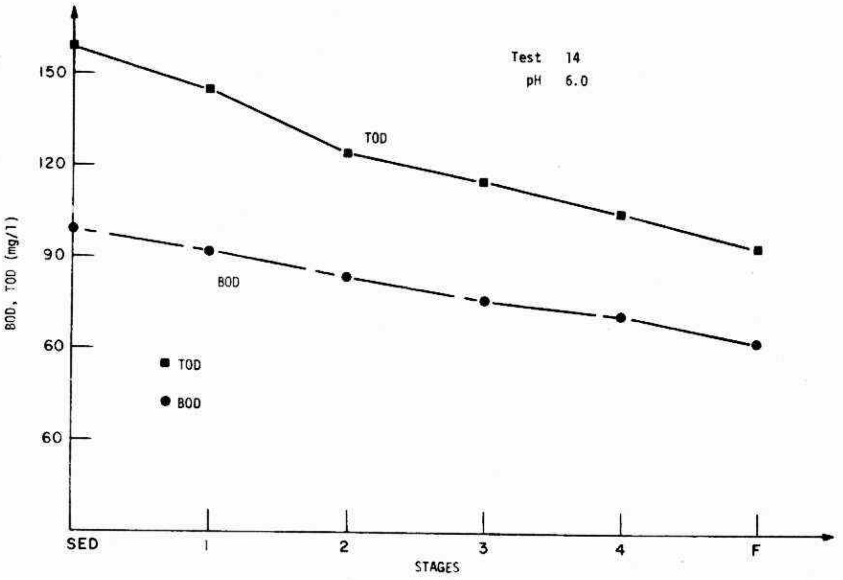

FIGURE 8 CONCENTRATION OF ORGANIC POLLUTANTS AT VARIOUS STAGES IN THE TREATMENT (pH 6.0)

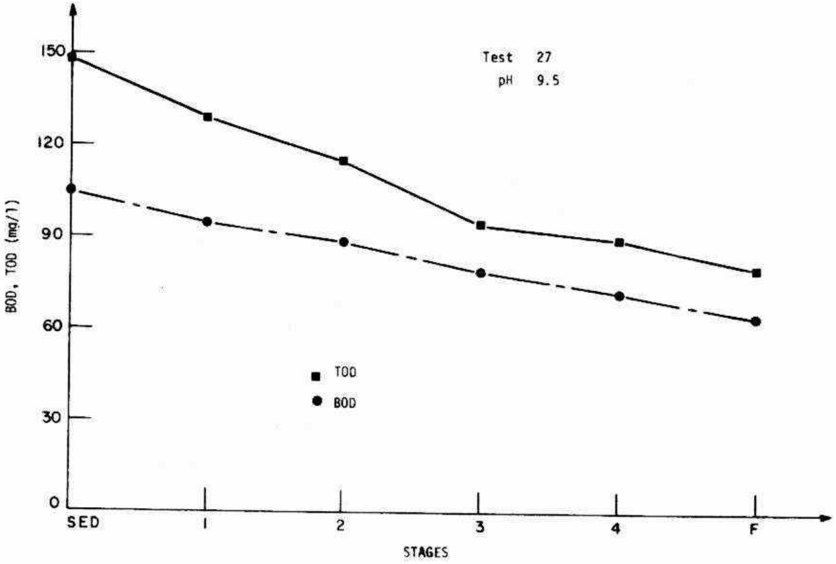

FIGURE 9 CONCENTRATION OF ORGANIC POLLUTANTS AT VARIOUS STAGES IN THE TREATMENT (pH 9.5)

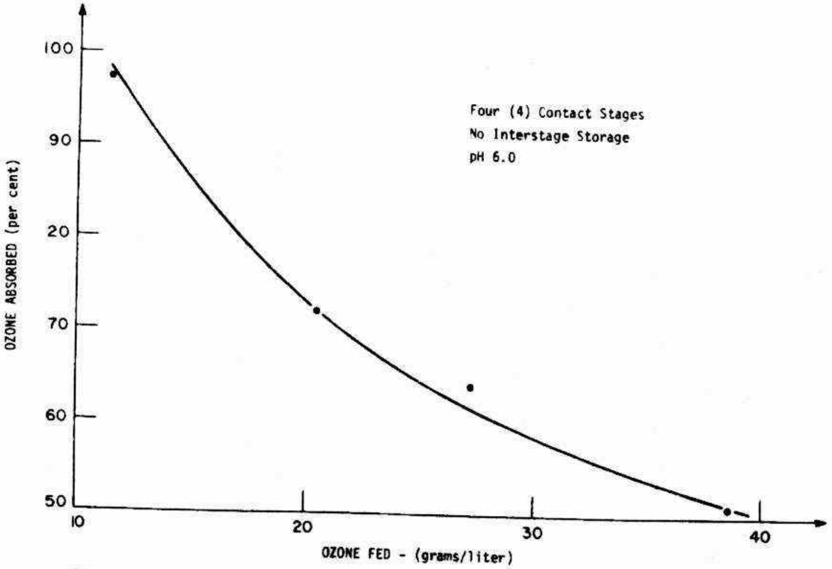

FIGURE 10 VARIATION OF FRACTION OF OZONE ABSORBED WITH INCREASING OZONE FEED RATE

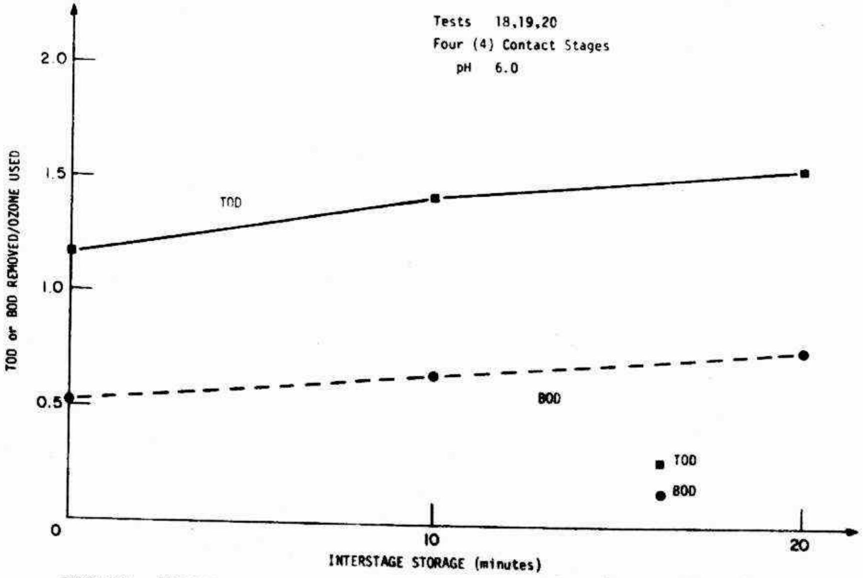

FIGURE 11 VARIATION OF OZONE EFFECTIVENESS BASED ON OZONE FEED RATE AS A FUNCTION OF INTERSTAGE STORAGE (four stages)

The above results were not sufficiently quantitative. Two new variables were defined in terms of ozone flow rates and TOD flow rates.

$$Z \equiv \frac{\text{TOD removed}}{\text{Ozone fed or used}}$$

$$Z \equiv \frac{\text{TOD removed}}{\text{Ozone absorbed in the liquid phase}}$$

These variables were also useful for analysing the effect of other parameters.

In Figures 11 and 12, Z increases with interstage storage, indicating the interstage storage may be useful. In Figure 13 and 14, Z^* is plotted against storage time. Essentially no effect is shown. Interstage storage had an effect on the ozone absorbed into the wastewater but none on the stoichiometrically required amount.

3.2.3 TOD removed per pound of ozone

Clearly, the question of how much ozone is required per pound of TOD is crucial. Its answer will determine the economic feasibility of ozone treatment. The ratio, Z^* has been found to be independent of interstage storage time but it does depend on a large number of parameters.

Ozone use efficiency could be a function of TOD concentration. Figure 15 shows the variation of Z^* with the initial wastewater concentration. For an initial concentration of 200 mg TOD/litre of water, one pound of ozone will remove 2.2 pounds of TOD. The amount of ozone required for one pound of TOD removal increases with decreasing initial TOD concentration.

One pound of ozone can oxidize more TOD than expected from some simple models. For instance, if only the third oxygen atom is an effective oxidizer, one would expect one pound of ozone to oxidize one third (0.33) pound of TOD. If all the oxygen of ozone is effective, one would expect one pound to oxidize one pound of TOD. The suggestion is here made that ozone initiates a chain reaction which employs dissolved oxygen in its propagation steps to oxidize TOD.

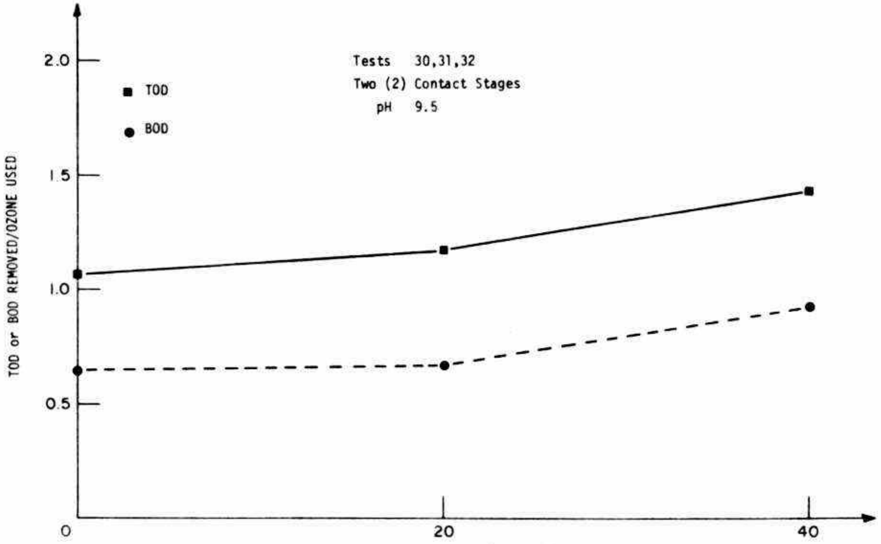

FIGURE 12 VARIATION OF OZONE EFFECTIVENESS BASED ON OZONE FEED RATE AS A FUNCTION OF INTERSTAGE STORAGE (two stages)

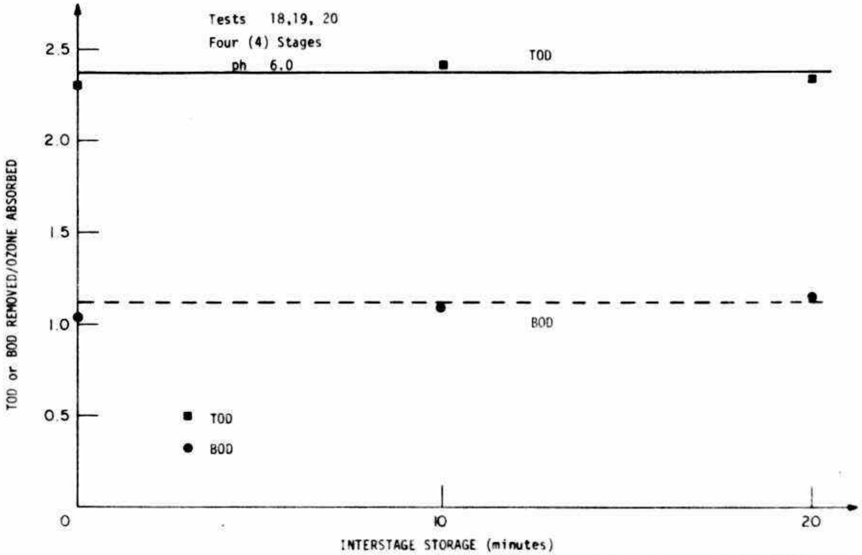

FIGURE 13 VARIATION OF OZONE EFFECTIVENESS BASED ON OZONE ABSORBED AS A FUNCTION OF INTERSTAGE STORAGE (four stages)

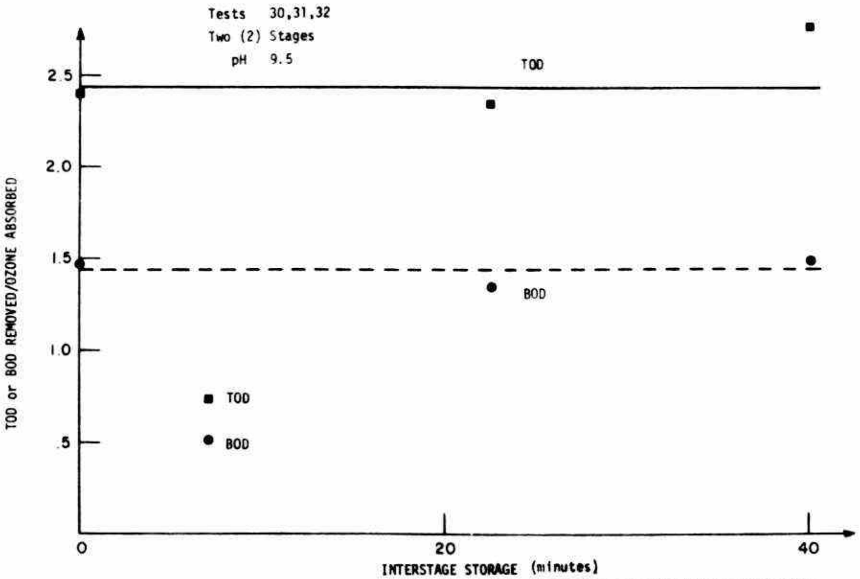

FIGURE 14 VARIATION OF OZONE EFFECTIVENESS BASED ON OZONE ABSORBED AS A FUNCTION OF INTERSTAGE STORAGE (two stages)

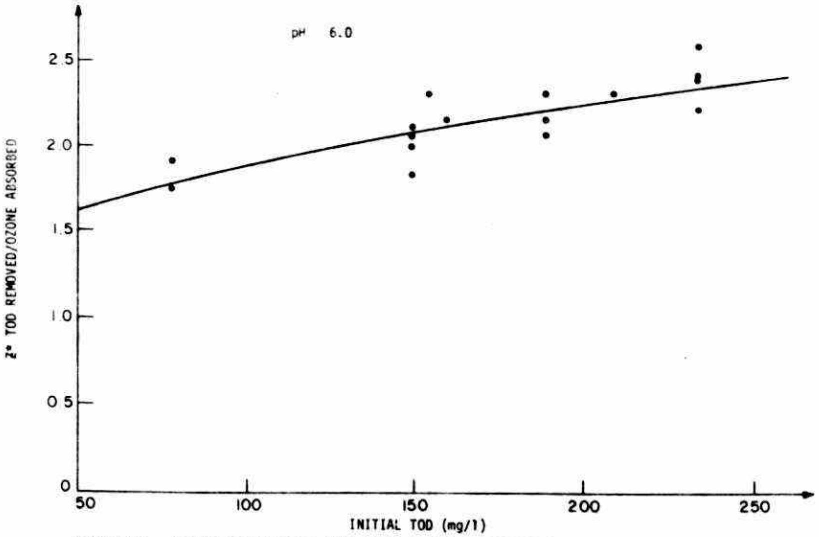

FIGURE 15 OZONE EFFECTIVENESS (Z*) BASED ON OZONE ABSORBED AS A FUNCTION OF INITIAL TOD

Wynn et al (1973) reported some data for the COD removed per pound of ozone absorbed in wastewater. The COD is not directly comparable to the TOD, but in most cases the COD is lower than the TOD. Their data cover a lower range than that covered in this study and the data agree where there is an overlap. One should note, however, that at low TOD's, the amount of ozone required to remove a given amount of TOD is much higher.

Figure 16 shows the same results for BOD removed/ozone consumed. The results are qualitatively similar to the TOD results.

3.2.4 Ultimate TOD reduction with ozone

Figures 8 and 9 demonstrated that although very good ozone reductions were possible, the quality of the effluent was not within the norms for effluent from a wastewater treatment plant.

Although substantial reductions of the TOD were obtained up to this point, there was no a priori guarantee that ozonation to obtain very low oxygen demands will be easy or even possible. Experience with pure organic compounds has demonstrated that although initial ozone attack may be very rapid, complete decomposition of a substance to CO_2 and H_2O is very difficult.

With these important objections in mind, a scheme was developed to test whether low TOD's or BOD's could be obtained. The addition of ozonation stages to the four stage pilot plant would have been very costly and time-consuming. The ozone generation equipment available would have been inadequate. It was decided to attempt something simpler.

Raw sewage was sent through the entire pilot plant once and then stored in one of the reservoirs. After approximately 500 gallons had been accumulated, the pilot plant was stopped and flushed out. The wastewater which had already been treated once was then treated a second time. The second treatment was started about four hours after the first one had been completed.

The results are plotted in a manner similar to that used for the four-stage plant. Figure 17 shows the results for four stages, a filter, four more stages, and a filter. The concentration of BOD was 190 mg/l before coagulation and 62 mg/l before ozonation. The final

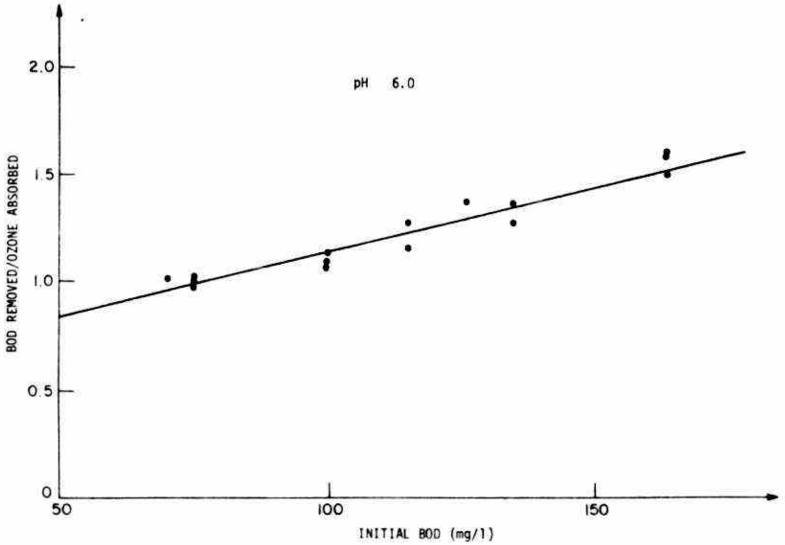

FIGURE 16 OZONE EFFECTIVENESS FOR BOD BASED ON OZONE ABSORBED AS A FUNCTION OF INITIAL BOD

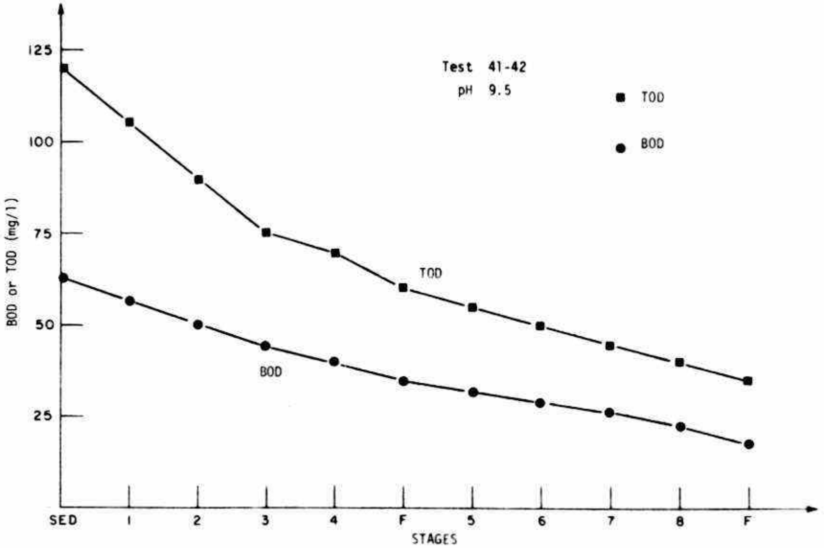

FIGURE 17 TEST OF OZONE'S ABILITY TO REDUCE ORGANIC POLLUTANTS TO REQUIRED LEVELS

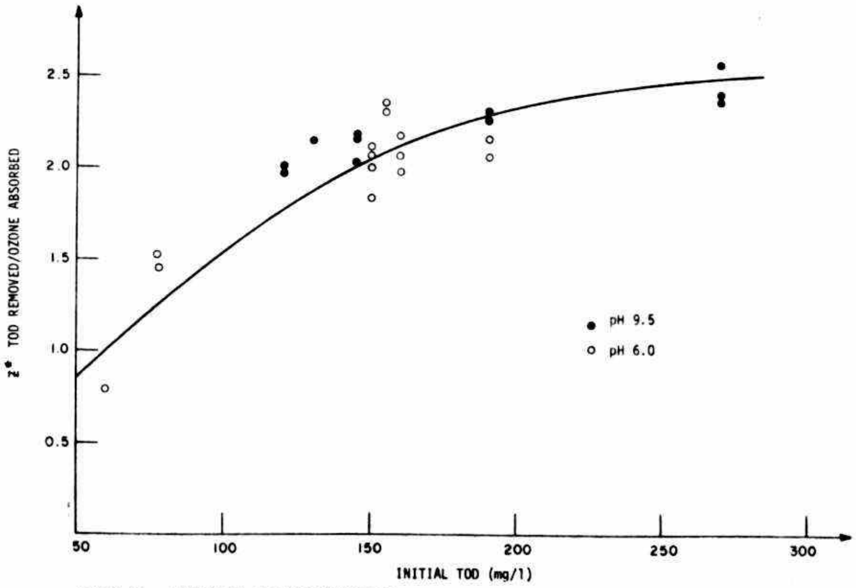

FIGURE 18 EFFECT OF pH ON STIOCHIOMETRY

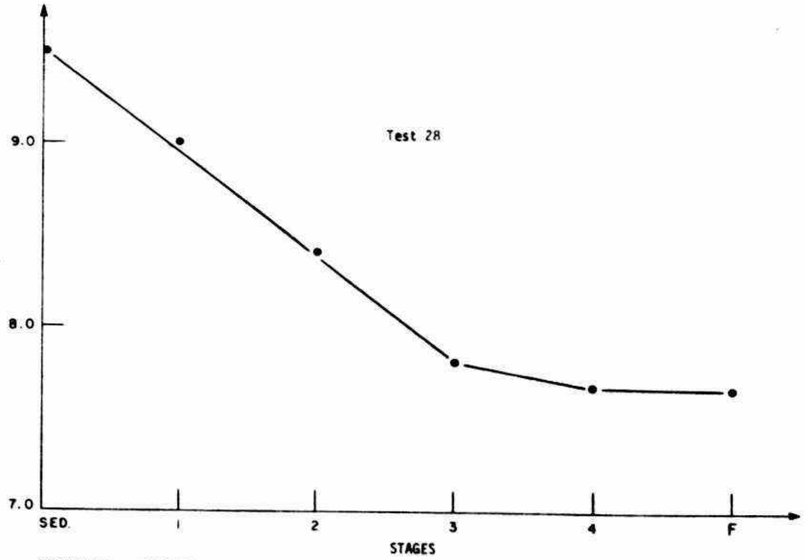

FIGURE 19 VARIATION OF pH DURING OZONATION

BOD was 16 mg/l. This would be a normally acceptable value. It should be recalled that the effluent from the ozonators was supersaturated with oxygen. The dissolved oxygen in the wastewater was, therefore, more than sufficient to oxidize any remaining BOD.

3.2.5 Effects of pH on the TOD reduction

Since the ozone initiates a chain reaction involving oxygen, it is possible that pH will have an effect not only on the reaction rates but also on the ozone effectiveness. Figure 18 is a graph of Z^*, the ozone effectiveness. There is no difference in the two curves at pH 6 and pH 9.5.

3.2.6 Ozone's effect on suspended solids

In all the tests performed in this study, the suspended solids increased as the wastewater travelled through the various contact stages. Boucher (1967) observed the same phenomena and called it micellization. He noted that ozone can act as a coagulant and reduce the negative zeta potential of colloidal particles. Other authors (Weingarden, 1971; Wynn *et al*, 1973) observed the opposite, i.e., suspended solids decreased when water was ozonated.

The suspended solids increase was probably related to the precipitation of iron compounds by oxidation of ferrous ion to ferric ion. During the process, it is possible that additional organic material was precipitated by the ferric ion formed. In the batch work, the most significant increases occurred when ferric chloride was used as a coagulant. The increases were much less with alum.

3.3 pH Variation during Ozonation

The pilot plant was built so as to be able to feed a constant pH wastewater to the sedimentation basin. The pH was not controlled as the wastewater flowed through the various contactors and holding tanks in the system.

Ozonation affects the pH of wastewater. Figure 19 shows the variation of pH as water flows through the pilot plant. In this case, the initial pH was alkaline and pH dropped to values of from 7.5 to 8.5 with time in the pilot plant. In cases where the pH is initially acidic, the pH rises to values of from 6.5 to 7.5. Figure 20 shows what happened in a number of experimental runs. All the experimental data demonstrated that ozonation causes the pH to become nearly neutral. Wynn et al (1973) observed the same results. To date, no adequate explanation has been found in the literature.

3.4 Ozone's Effect on Nitrogenous Compounds

The concentration of nitrogenous compounds was followed very closely throughout the pilot plant runs. It was expected that ozone could affect the nutrient content of the effluent from the wastewater plant. At the very least, ozone might oxidize ammonia and organic nitrogen to nitrates, eliminating the nitrogenous demand of the wastewater. To study these possibilities analyses were made at various points for organic nitrogen, ammonia nitrogen, nitrites, and nitrates.

Table 1 shows the effect of major elements of the treatment on the important nitrogen content variables. In line with the observation that stripping of ammonia occurs in alkaline solutions, overall removal of nitrogenous compounds was highest at high pH. In general, the results were unspectacular. Removal in the sedimentation was as important as one might expect. The most disappointing finding was that oxidation of organic and ammonia nitrogen did not occur to a large degree.

3.5 Ozone's Effect on Phosphates

In the pilot plant, very good results were obtained for the removal of phosphates from wastewater. In general, 75 to 90% of the phosphates were removed by coagulation and sedimentation from wastewater with an initial concentration of 3-17 mg/l of total phosphates.

Ozone itself had no influence on the concentration of phosphates. However, as mentioned above, ozone had produced a pronounced increase in the concentration of suspended solids. The increase in suspended solids made it possible for the filter to remove a fraction of the phosphates, which would otherwise be impossible. These results are presented in Figure 21.

TABLE 1. REMOVAL OF NITROGENOUS COMPOUNDS

The following are the fractional changes observed in the concentration of nitrogenous compounds in the various units of the pilot plant. Unless stated otherwise, the changes are percentile reductions. Typical starting concentrations were:

Total N	12-20 mg/l	as nitrogen
Org N	2-4 mg/l	as nitrogen
NH_3	7-19 mg/l	as nitrogen
NO_3	0-1 mg/l	as nitrogen

Nitrite concentrations were always very low.

Treatment unit	Total N	NH_3-N	Org N	NO_3-N
Coagulation-Sedimentation	15-20	5-10	50-65	small increase
Ozonation				
pH = 6.0	15-20	15-25	15-25	2-4 fold increase
pH = 9.5	25-30	30-40	30-40	4-8 fold increase
Filter	<5	≃0	25-35	≃0
Overall				
pH = 6.0	30-40	20-30	65-85	2-4 fold increase
pH = 9.5	45-55	35-45	70-85	4-8 fold increase

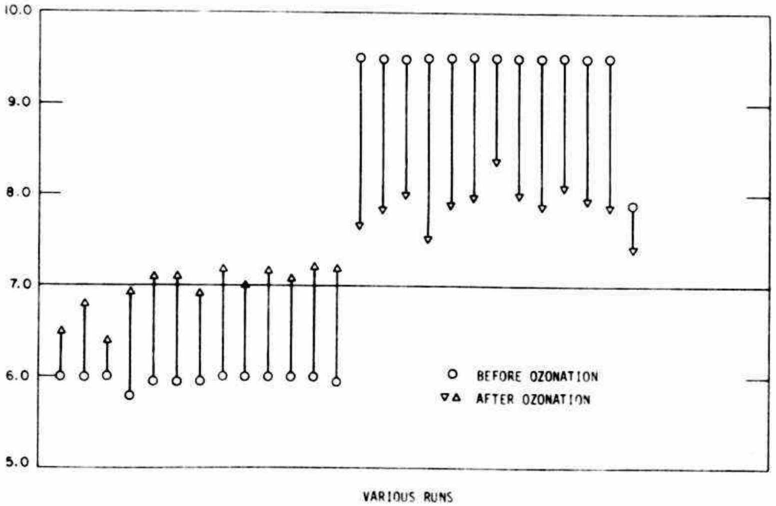

FIGURE 20 **VARIATION OF pH FOR A NUMBER OF RUNS**

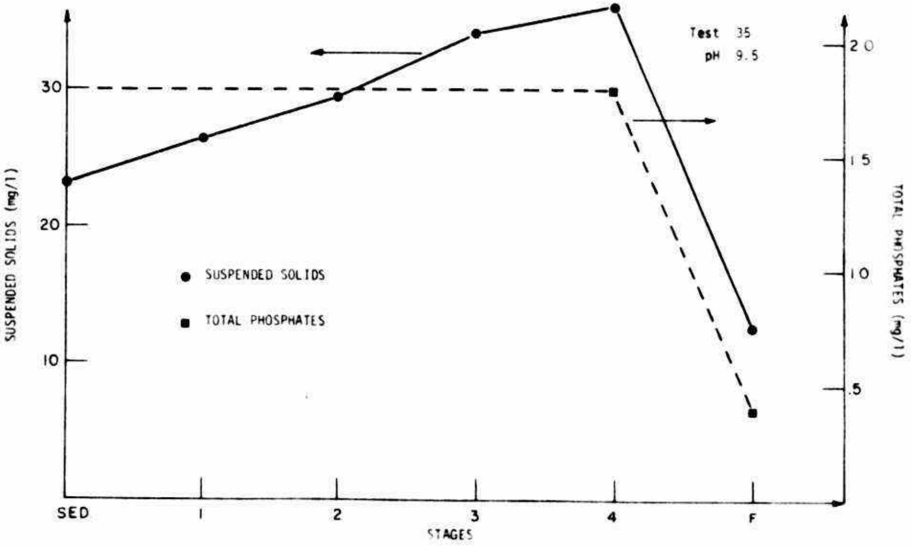

FIGURE 21 **VARIATION OF TOTAL PHOSPHATES AND** SUSPENDED SOLIDS DURING OZONATION

4. ECONOMIC ANALYSIS OF OZONE TREATMENT

4.1 Introduction

The economic analyses of processes still in the early stages of development are fraught with uncertainties. It is often necessary to proceed with the economic analysis before the process flow sheet is firmly established. It is difficult to obtain realistic costs for many of the equipment elements during this early period, and these problems are in addition to the normal uncertainties which exist in estimating the cost of even a well established plant design. Obviously one should be cautious of the absolute costs predicted and even more cautious of comparisons of these costs with the costs of existing processes.

Huibers et al (1969) calculated that ozone treatment to reduce COD from 35 mg/l to 15 mg/l would cost 7.7 cents per thousand gallons in a 10 US mgd plant. For the same size plant and the same COD reduction, Wynn et al (1973) calculated that ozone treatment of wastewater would cost 12.4 cents per 1000 gallons. Wynn et al also calculated the costs for other sizes of plants and found that there were important economies of scale.

Weber (1972) calculated that direct physicochemical treatment with activated carbon would cost 20.5 cents per thousand gallons in a 10 US mgd plant. In this report the values of Weber and Wynn were combined in order to compare direct physicochemical treatment with activated carbon to direct physicochemical treatment with ozone.

4.2 Base Case

In order to compare the results of Weber, Wynn and this investigation, the following economic study has been based on information from the last quarter of 1971.

The hydraulic load was 10 US mgd. Influent TOD and BOD were 275 and 190, respectively. (This corresponds to runs 41 and 42 in Appendix III, the extended ozonation results.) It was found that if 77 mg/l were applied and 51 mg/l were consumed, the TOD and BOD could be reduced to 35 and 16 mg/l, respectively. Therefore, a dosage of 75 mg/l was used for calculation purposes. If the ozone use efficiency could be improved, an even greater reduction of organic pollutants is possible.

Electricity was assumed to cost 0.8 cents per kwh (Hydro Quebec, 1974) a number which continues to be useful in a Canadian context. This cost includes the demand charge. Interest charges are 8%. This is representative of the costs Canadian municipalities are likely to incur.

4.3 Physicochemical Treatment with Activated Carbon

Tables 2 and 3 show the costs for direct physicochemical treatment of wastewater which Weber (1972) predicted for activated carbon. Some small corrections have been made to make these data correspond to our base case. For example, electricity was costed at $0.008/kwh, and amortization was 24 years at 8%.

The total annual cost when these adjustments have been made is 21.7 cents per thousand gallons. To remind us of the danger of comparing such costs to existing plants, consider activated sludge plants. 10 US mgd plants have cost as much as $10,000,000.00. The interest charges alone at 8% are 21.9 cents per thousand gallons for such a plant.

4.4 Costs of Direct Physicochemical Treatment with Ozone

Tables 4 and 5 show the estimated costs for direct physicochemical treatment of wastewater with ozone. The cost estimate for ozone treatment uses data included in the report by Wynn et al (1973). The results of Bowers et al (1973) suggest that capital cost to produce the required amount of ozone (6000 lb/day) would be about $800,000. The additional $700,000 would be associated equipment. The injection of ozone was assumed rather than spraying because most indications are that this is more economical. The use of pure oxygen was assumed. Pure oxygen should be more economical in 10 US mgd plants. In general, the labour was estimated in a manner consistent with Weber's (1972) report of costs.

The cost of direct physicochemical treatment with ozone is 25.5 cents per thousand gallons when estimated so as to be on a similar basis to that of Weber. Ozonation is, therefore, slightly more expensive than activated carbon treatment, which would cost 21.9¢/1000 gallons.

Ozonation with pure oxygen performs two other important functions that carbon adsorption does not. The water leaving the ozonation plant is supersaturated with oxygen and the aeration process sometimes required

TABLE 2. ESTIMATED CAPITAL COSTS FOR DIRECT PHYSICOCHEMICAL TREATMENT OF WASTEWATERS WITH ACTIVATED CARBON (WEBER, 1972). BASIS: 10 US mgd

	Total Cost
Equipment, Piping and Instrumentation	
Pretreatment and Flocculation	$ 154,000
Clarification and Sludge Handling	1,113,600
Adsorption System	617,600
Regeneration System	222,500
Auxiliary Facilities	
Electric Power	80,000
Fuel Handling	20,000
Buildings and Structures	493,000
Roads, Walks, Fence	170,000
Activated Carbon	288,000
Contingency	390,000
Total Fixed Capital	$ 3,548,700

TABLE 3. ESTIMATED ANNUAL OPERATING COSTS FOR DIRECT PHYSICOCHEMICAL TREATMENT OF WASTEWATER WITH ACTIVATED CARBON.
BASIS: 10 US mgd

		Packed
1.	Operating Labour*	$ 86,600
2.	Maintenance Labour	55,600
3.	Maintenance Materials	37,000
4.	Maintenance Supplies - 15% of (2) + (3)	13,900
5.	Supervision - 15% of (1)	13,000
6.	Payroll Overhead - 15% of (1) + (2)	21,000
7.	General Overhead - 30% of (1) + (2) + (6)	49,100
8.	Insurance	18,600
9.	Carbon Makeup - 5% @ $.28/lb	27,500
10.	Lime Makeup - 25% @ $20/T	23,000
11.	Fuel - @ $.50/MM Btu	75,000
12.	Power - $.008/kwh	36,000
13.	Amortization - 24 years @ 8%	337,000
	Total Annual Cost	$793,300
	Treatment Cost - ¢/1000 gal.	21.7

*2 Shift men + 2 day men @ $4.00 per hour

TABLE 4. ESTIMATED CAPITAL COSTS FOR DIRECT PHYSICOCHEMICAL TREATMENT OF WASTEWATERS WITH OZONE. BASIS: 10 US mgd, 75 mg/l Ozone Dosage

Equipment, Piping and Instrumentation		
Pretreatment and Flocculation		$ 154,000
Clarification and Sludge Handling		1,114,000
Ozonation		1,520,000
Auxiliary Facilities		
Electric Power		140,000
Buildings and Structures		493,000
Roads, Walk, Fence		170,000
Contingency 12%		431,000
	Total Cost	$4,022,000

TABLE 5. ESTIMATED ANNUAL OPERATING COSTS FOR DIRECT PHYSICOCHEMICAL TREATMENT OF WASTEWATER WITH OZONE. BASIS: 10 US mgd, 75 mg/litre Ozone dosage

1.	Operating Labour	$ 86,600
2.	Maintenance Labour	55,600
3.	Maintenance Materials	37,100
4.	Maintenance Supplies 15% of (2) + (3)	13,900
5.	Supervision - 15% of (1)	13,000
6.	Payroll Overhead 15% of (1) + (2)	21,000
7.	General Overhead 30% of (1) + (2) + (6)	49,100
8.	Insurance	18,600
9.	Lime Makeup - 25% @ $20/T	23,000
10.	Fuel @ .50/MM Btu	37,000
11.	Power @ $.008/kwh	151,000
12.	Oxygen	44,000
13.	Amortization - 24 years @ 8%	382,000
	Total Annual Cost	$931,900
	Treatment Cost - ¢/1000 gal	25.5

is eliminated. Also chlorination, which is not always recommended and would cost from 1 to 2 cents per thousand gallons, is eliminated.

4.5 Discussion

The costs of direct physicochemical treatment using activated carbon or ozone are comparable. Ozonation performs the triple function of COD reduction, aeration, and disinfection of the effluent without the necessity of adding toxic chlorine to the effluent from the treatment plant. There are uncertainties in the costs used for ozone treatment but there are perhaps more in the activated carbon study. Weber stated that only 5% of activated carbon's adsorption capacity would be lost during each regeneration. This has not yet been proven. The case for the continuing of the development of ozonation processes is strong.

ACKNOWLEDGMENTS

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APPENDIX I

ABBREVIATIONS AND SYMBOLS

APPENDIX I

Abbreviations and Symbols

BOD_5	five-day Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
mg/l	milligrams per litre
NH_3-N	ammonia as nitrogen
NO_3-N	nitrates as nitrogen
org-N	organic nitrogen as nitrogen
ppm	parts per million
TOD	Total Oxygen Demand
US gpm	United States gallons per minute
US mgd	millions of United States gallons per day
Z	milligrams TOD removed/milligrams ozone fed or used
Z^*	milligrams TOD removed/milligrams ozone absorbed into the liquid phase

APPENDIX II

ANALYTICAL METHODS

APPENDIX II

Analytical Methods

TOD

All these analyses were made with an Ionics TOD analyser. The precision is about 5 mg/l.

Ozone Dissolved in Water

A slightly modified version of the procedure on page 271 of Standard Methods (1971) was used.

Before performing the analysis, 100 ml of 2% KI solution and five drops of 5% KOH solution were placed in a 250 ml graduated cylinder. The wastewater was quickly introduced into the graduated cylinder up to the 250 ml mark. The cylinder and its contents were shaken and three ml of 1 N H_2SO_4 were added. The contents were subsequently titrated with a 0.025 N solution of sodium thiosulphate using starch as an indicator.

Ozone in Air

Gaseous samples for ozone determination were taken in an evacuated glass bulb of 2.1 litre capacity. Immediately after taking the sample, 100 ml of 2% potassium iodide solution (pH 11) were added with a specially constructed syringe. The bulb was vigorously agitated, the pH was adjusted to acid conditions with three ml of 1 N sulphuric acid, and, finally, the contents were titrated with 0.1 N sodium thiosulphate.

Suspended Solids

A sample of 100 ml was filtered through a matched pair of 0.45 μ Millipore filters. The two filters were dried for 24 hours at 70°C and weighed. The difference yielded the suspended solids.

pH

pH was measured with a Fisher pH meter (Model Accumet 320).

Other Analyses

The other analyses were performed according to methods suggested in *Standard Methods.*

BOD_5	Aside Modification of the Winkler Method	p. 489 - 95
Dissolved O_2	Aside Modification of the Winkler Method	p. 477 - 81
PO_4 total	Persulphate + Stannous Chloride	p. 520, 526, 530 - 2
PO_4 ortho	Stannous Chloride	p. 520 - 1, 530 - 2
NO_2-N	Diazotization Method	p. 240 - 3
NO_3-N	Brucine Method	p. 461 - 4
NH_3-N	Kjeldahl Method	p. 244 - 8
Org - N	Kjeldahl Method + Digestion	p. 244 - 8

APPENDIX III

EXPERIMENTAL DATA

APPENDIX III

Experimental Data

The data for all the runs were entered on punch cards so that various analyses and clear reports could be produced. An explanation of the more difficult symbols follows.

Sample Point

The sample point, and occasionally the pretreatment the sample received, is identified by a code followed by three numbers (e.g. Code XXX).

First Number: refers to the unit in question

1	coagulation unit
2	ozonation unit
3	filter

Second Number: refers to the step in the unit referred to

0	influent except for the filter where it is the effluent
1,2,3,4	effluent of a particular stage, only has meaning for ozone unit

Third Number: special situations

0	no additional information is provided
1	sample taken after half the interstage storage has occurred
2	sample taken between the contact chamber and the interstage storage
9	sample was filtered in a paper filter before analysis

Other symbols:

Residence time interstage storage (min)

Coagulant	1 refers to $FeCl_3$ 2 refers to $FeCl_3$ + CaO
Q	dose of $FeCl_3$ as Fe

Feed Rate	total wastewater feed rate
Res O_3	is the O_3 present in the gas stream after ozonation in mg/l
Dissolved O_3	is the O_3 present in the water after ozonation in mg/l

Peculiarities of Certain Tests:

Number 1	Test for the coagulation unit only
Numbers 2-7	The filter was not yet working and samples were filtered with Whatman #1 paper for some analyses
Numbers 21-26	Only the TOD, dissolved oxygen, and dissolved ozone were measured
Number 42	The second part is a special test to see whether low BOD's could be obtained. The wastewater had already been treated in Test No. 41

Test No. 1

Wastewater Feed 3.0 US gpm
Residence Time 0.0
Coagulant 1

O_2 Flow Rate 0.0 l/min.
Q 40.0 ppm

O_3 Fed 0.0 g/hr
O_3 Used
O_3 Consumed

CODE	pH	DISS. O_2	DISS. O_3	RES. O_3	TOD	BOD	SS	TOTAL PO_4	ORTHO PO_4	NO_2	NO_3	AMM	ORG N	TOTAL N
100	--	0.0	--	--	715.	225.	390.0	2.95	1.16	0.72	0.20	9.50	2.10	12.52
200	--	3.5	—	—	300.	90.	3.0	0.14	0.07	0.15	1.75	6.40	0.70	9.00
200	—	3.2	—	—	305.	95.	11.0	0.24	0.09	0.15	1.75	6.40	0.70	9.00
200	—	3.4	—	—	300.	90.	4.0	0.14	0.07	0.14	1.75	6.20	0.90	8.99

Test No. 2

Wastewater Feed 3.0 US gpm
Residence Time 0.0
Coagulant 1

O_2 Flow Rate 12.6 l/min.
Q 32.0 ppm

O_3 Fed 18.5 gm/hr
O_3 Used 27.2 mg/l
O_3 Consumed 17.4 mg/l

CODE	pH	DISS. O_2	DISS. O_3	RES. O_3	TOD	BOD	SS	TOTAL PO_4	ORTHO PO_4	NO_2	NO_3	AMM	ORG N	TOTAL N
100	--	0.0	0.0	—	340.	180.	97.0	7.80	3.80	0.70	0.55	9.40	3.80	14.45
200	--	1.2	0.0	—	250.	128.	76.0	3.00	1.80	0.57	0.75	8.90	1.90	12.12
209	—	—	—	—	200.	106.	—	3.00	1.60	0.57	0.55	8.90	1.80	11.82
210	--	22.1	6.2	0.8	230.	120.	66.0	3.00	1.80	—	—	--	--	--
219	—	--	—	—	175.	96.	—	2.60	1.50	—	—	--	--	--
220	--	27.5	10.4	2.5	220.	112.	68.0	3.10	1.90	—	—	—	--	--
229	—	--	—	—	170.	94.	—	2.60	1.30	—	—	—	--	--
230	—	28.4	10.9	14.7	190.	105.	65.0	3.05	1.80	—	—	—	—	--
239	—	--	—	—	160.	88.	—	2.50	1.30	—	—	—	—	—
240	--	29.2	10.8	17.0	180.	100.	66.0	3.00	1.80	0.0	1.80	7.10	1.70	10.60
249	—	—	—	—	155.	80.	—	2.45	1.10	0.0	1.70	7.10	0.90	9.60

Test No. 3

Wastewater Feed 3.0 US gpm
Residence Time 0.0
Coagulant 1

O_2 Flow Rate 11.6 l/min.
Q 32.0 ppm

O_3 Fed 13.9 g/hr
O_3 Used 20.4 mg/l
O_3 Consumed 14.5 mg/l

CODE	pH	DISS. O_2	DISS. O_3	RES. O_3	TOD	BOD	SS	TOTAL PO_4	ORTHO PO_4	NO_2	NO_3	AMM	ORG N	TOTAL N
100	--	0.0	0.0	—	340.	180.	97.0	7.80	3.80	0.70	0.55	9.40	3.80	14.55
200	—	0.9	0.0	—	235.	126	75.0	3.00	1.80	0.56	0.75	9.00	1.80	12.11
209	—	--	—	—	190.	104.	—	3.00	1.60	0.57	0.55	8.70	1.70	11.52
210	—	20.2	5.0	0.8	225.	116.	66.0	2.95	1.80	—	—	—	—	--
219	--	—	—	—	180.	84.	—	2.80	1.60	—	—	—	—	—
220	—	24.2	9.1	0.5	215.	110.	68.0	3.00	1.80	—	—	—	—	—
229	—	—	—	—	175.	82.	—	2.80	1.50	—	—	--	—	--
230	--	28.6	10.2	8.0	205.	106.	63.0	2.90	1.80	—	—	—	—	--
239	--	—	—	—	170.	80.	—	2.75	1.40	—	—	—	—	--
240	--	29.5	10.6	13.8	200.	106.	69.0	3.00	1.80	0.0	1.25	7.20	1.70	10.15
249	--	—	—	--	160.	78.	—	2.70	1.20	0.0	1.25	7.20	1.10	9.55

Test No. 4

Wastewater Feed 3.0 US gpm
Residence Time 0.0
Coagulant 1

O_2 Flow Rate 9.5 l/min.
Q 32.0 ppm

O_3 Fed 7.8 g/hr
O_3 Used 11.4 mg/l
O_3 Consumed 10.9 mg/l

CODE	pH	DISS. O_2	DISS. O_3	RES. O_3	TOD	BOD	SS	TOTAL PO_4	ORTHO PO_4	NO_2	NO_3	AMM	ORG N	TOTAL N
100	—	0.0	0.0	—	340.	180.	97.0	7.80	3.80	0.70	0.55	9.40	3.80	14.55
200	--	1.0	0.0	--	210.	124.	69.0	3.00	1.80	0.57	0.80	8.70	1.30	11.37
209	--	--	--	—	165.	102.	--	3.00	1.60	0.57	0.55	8.60	1.20	10.92
210	--	22.0	2.6	0.8	205.	114.	70.0	3.00	1.80	—	--	—	--	--
219	--	--	—	—	150.	92.	--	2.90	1.60	—	—	—	--	--
220	--	23.0	4.4	0.5	200.	112.	70.0	2.95	1.70	—	—	—	—	--
229	—	--	--	—	140.	90.	--	2.90	1.50	—	--	--	—	--
230	--	23.0	6.4	0.6	190.	110.	66.0	2.95	1.80	--	--	--	--	--
239	--	--	--	—	140.	90.	--	2.85	1.50	—	--	—	—	--
240	—	23.0	8.5	0.8	185.	108.	52.0	2.95	1.80	0.0	0.90	7.90	1.20	10.00
249	--	--	--	—	135.	86.	--	2.80	1.30	0.0	0.90	7.90	0.90	0.90

Test No. 5

Wastewater Feed 3.0 US gpm
Residence Time 0.0
Coagulant 1

O_2 Flow Rate 12.6 1/min.
Q 50.0 ppm

O_3 Fed 18.5 g/hr
O_3 Used 27.2 mg/1
O_3 Consumed 17.4 mg/1

CODE	pH	DISS. O_2	DISS. O_3	RES. O_3	TOD	BOD	SS	TOTAL PO_4	ORTHO PO_4	NO_2	NO_3	AMM	ORG N	TOTAL N
100	--	0.0	0.0	--	490.	430.	174.8	7.40	2.70	0.13	0.55	16.10	1.90	18.68
200	--	0.1	0.0	--	235.	164.	24.0	0.29	0.07	0.10	0.65	14.30	1.10	16.15
209	--	--	--	--	195.	135.	--	0.28	0.07	0.10	0.60	14.30	1.10	16.10
210	--	20.6	6.1	0.7	220.	155.	24.0	--	--	--	--	--	--	--
219	--	--	--	--	180.	120.	--	--	--	--	--	--	--	--
220	--	26.5	10.4	2.5	210.	149.	25.0	--	--	--	--	--	--	--
229	--	--	--	--	170.	115.	--	--	--	--	--	--	--	--
230	--	27.8	10.9	14.7	200.	142.	25.0	--	--	--	--	--	--	--
239	--	--	--	--	155.	108.	--	--	--	--	--	--	--	--
240	--	29.0	10.8	17.2	190.	136.	26.0	0.28	0.03	0.05	2.55	12.00	0.80	15.40
249	--	--	--	--	150.	102.	--	0.08	0.03	0.04	2.40	11.80	0.80	15.04

Test No. 6

Wastewater Feed 3.0 US gpm
Residence Time 0.0
Coagulant 1

O_2 Flow Rate 11.6 1/min.
Q 50.0 ppm

O_3 Fed 13.9 g/hr
O_3 Used 20.4 mg/1
O_3 Consumed 14.7 mg/1

CODE	pH	DISS. O_2	DISS. O_3	RES. O_3	TOD	BOD	SS	TOTAL PO_4	ORTHO PO_4	NO_2	NO_3	AMM	ORG N	TOTAL N
100	--	0.0	0.0	--	490.	430.	174.0	7.40	2.70	0.13	0.55	16.10	1.90	18.68
200	--	0.1	0.0	--	235.	164.	24.0	0.29	0.07	0.10	0.65	14.30	1.10	16.15
209	--	--	--	--	195.	132.	--	0.28	0.07	0.10	0.60	14.30	1.00	16.00
210	--	20.4	5.0	0.8	225.	160.	24.0	--	--	--	--	--	--	--
219	--	--	--	--	190.	132.	--	--	--	--	--	--	--	--
220	--	22.0	8.9	0.4	215.	152.	25.0	--	--	--	--	--	--	--
229	--	--	--	--	175.	124.	--	--	--	--	--	--	--	--
230	--	27.4	10.3	8.1	205.	146.	26.0	--	--	--	--	--	--	--
239	--	--	--	--	165.	116.	--	--	--	--	--	--	--	--
240	--	29.1	10.5	12.9	200.	142.	27.0	0.29	0.04	0.06	2.00	12.20	0.80	15.06
249	--	--	--	--	165.	110.	--	0.08	0.04	0.05	2.00	12.00	0.70	14.75

Test No. 7

Wastewater Feed 3.0 US gpm
Residence Time 0.0
Coagulant 1

O_2 Flow Rate 0.5 1/min.
Q 50.0 ppm

O_3 Fed 7.8 g/hr
O_3 Used 11.4 mg/1
O_3 Consumed 11.3 mg/1

CODE	pH	DISS. O_2	DISS. O_3	RES. O_3	TOD	BOD	SS	TOTAL PO_4	ORTHO PO_4	NO_2	NO_3	AMM	ORG N	TOTAL N
100	--	0.0	0.0	--	490.	430.	175.0	7.40	2.70	0.13	0.55	16.10	1.90	18.68
200	--	0.1	0.0	--	235.	164.	24.0	0.29	0.07	0.10	0.65	14.30	1.10	16.15
209	--	--	--	--	195.	132.	--	0.28	0.07	0.10	0.60	14.20	1.10	16.00
210	--	22.0	2.6	0.5	230.	158.	23.0	--	--	--	--	--	--	--
219	--	--	--	--	195.	130.	--	--	--	--	--	--	--	--
220	--	23.1	4.5	0.1	225.	154.	24.0	--	--	--	--	--	--	--
229	--	--	--	--	185.	124.	--	--	--	--	--	--	--	--
230	--	23.2	6.5	0.1	215.	148.	24.0	--	--	--	--	--	--	--
239	--	--	--	--	175.	120.	--	--	--	--	--	--	--	--
240	--	24.1	8.4	0.1	210.	146.	25.0	0.29	0.04	0.06	1.45	13.20	0.90	15.61
249	--	--	--	--	175.	118.	--	0.08	0.04	0.06	1.40	13.20	0.80	15.46

Test No. 8

Wastewater Feed 3.0 US gpm
Residence Time 20.0
Coagulant 1

O_2 Flow Rate 12.6 1/min.
Q 45.0 ppm

O_3 Fed 18.5 g/hr
O_3 Used 27.2 mg/1
O_3 Consumed 23.3 mg/1

CODE	pH	DISS. O_2	DISS. O_3	RES. O_3	TOD	BOD	SS	TOTAL PO_4	ORTHO PO_4	NO_2	NO_3	AMM	ORG N	TOTAL N
100	7.2	0.4	0.0	--	470.	205.	98.0	5.20	2.30	0.0	0.20	9.20	2.80	12.20
200	6.0	2.3	0.0	--	190.	135.	6.0	0.10	0.02	0.14	0.20	8.60	1.00	9.94
210	--	22.1	3.8	0.7	175.	125.	8.0	--	--	--	--	--	--	--
220	--	27.5	6.6	0.8	160.	115.	11.3	--	--	--	--	--	--	--
230	--	28.9	6.6	3.0	145.	108.	11.1	--	--	--	--	--	--	--
240	6.4	29.0	6.8	9.5	140.	103.	16.1	0.11	0.02	0.01	1.20	7.80	0.10	9.11
300	6.5	24.5	5.4	--	130.	95.	8.0	0.03	0.01	0.01	1.20	7.80	0.10	9.11

Test No. 9

Wastewater Feed 3.0 US gpm
Residence Time 20.0
Coagulant 1

O_2 Flow Rate 11.6 l/min.
Q 45.0 ppm

O_3 Fed 13.9 g/hr
O_3 Used 20.4 mg/l
O_3 Consumed 19.6 mg/l

CODE	pH	DISS. O_2	DISS. O_3	RES. O_3	TOD	BOD	SS	TOTAL PO_4	ORTHO PO_4	NO_2	NO_3	AMM	ORG N	TOTAL N
100	8.0	0.4	0.0	--	470.	235.	98.0	5.20	2.30	0.0	0.18	9.20	2.80	12.80
200	6.0	2.8	0.0	--	190.	135.	6.9	0.10	0.02	0.13	0.20	8.90	1.00	9.33
210	6.4	20.2	3.0	0.8	175.	126.	12.4	--	--	--	--	--	--	--
220	6.6	23.9	4.5	0.7	160.	120.	13.2	--	--	--	--	--	--	--
230	6.6	24.8	5.3	0.7	150.	114.	14.2	--	--	--	--	--	--	--
240	6.8	27.5	6.0	1.0	145.	110.	13.5	0.10	0.02	0.01	1.20	7.90	0.10	9.49
300	6.8	24.8	5.2	--	135.	100.	5.0	0.04	0.01	0.01	1.20	7.90	0.10	9.47

Test No. 10

Wastewater Feed 3.0 US gpm
Residence Time 20.0
Coagulant 1

O_2 Flow Rate 11.6 l/min.
Q 40.0 ppm

O_3 Fed 13.9 g/hr
O_3 Used 20.4 mg/l
O_3 Consumed 10.5 mg/l

CODE	pH	DISS. O_2	DISS. O_3	RES. O_3	TOD	BOD	SS	TOTAL PO_4	ORTHO PO_4	NO_2	NO_3	AMM	ORG N	TOTAL N
100	7.4	0.0	0.0	--	455.	200.	213.0	6.00	2.60	0.01	0.20	8.40	3.10	11.71
200	5.8	1.2	0.0	--	190.	115.	7.6	0.40	0.05	0.04	0.20	8.20	1.10	9.54
210	6.2	16.5	7.6	0.9	180.	104.	10.0	--	--	--	--	--	--	--
220	6.8	16.5	4.4	0.7	175.	100.	11.3	--	--	--	--	--	--	--
230	6.8	22.0	5.2	0.7	160.	94.	12.6	--	--	--	--	--	--	--
240	7.0	24.0	6.4	1.2	150.	90.	16.1	0.40	0.05	0.0	1.10	6.40	0.20	7.70
300	7.0	19.6	4.9	--	140.	82.	4.5	0.22	0.01	0.0	1.00	6.30	0.20	7.50

Test No. 11

Wastewater Feed 3.0 US gpm
Residence Time 20.0
Coagulant 1

O_2 Flow Rate 12.6 l/min.
Q 40.0 ppm

O_3 Fed 18.5 g/hr
O_3 Used 27.2 mg/l
O_3 Consumed 23.3 mg/l

CODE	pH	DISS. O_2	DISS. O_3	RES. O_3	TOD	BOD	SS	TOTAL PO_4	ORTHO PO_4	NO_2	NO_3	AMM	ORG N	TOTAL N
100	7.4	0.0	0.0	--	455.	200.	213.0	6.00	2.60	0.10	0.20	8.40	3.10	11.80
200	5.8	5.8	0.0	--	190.	115.	8.9	0.40	0.05	0.40	0.20	8.10	1.10	9.80
210	6.4	26.4	3.9	0.7	175.	106.	10.9	--	--	--	--	--	--	--
220	6.5	28.4	6.7	0.6	155.	100.	10.6	--	--	--	--	--	--	--
230	6.7	28.7	6.9	3.0	145.	94.	15.8	--	--	--	--	--	--	--
240	6.9	28.9	6.9	9.5	140.	88.	20.4	0.40	0.05	0.0	1.30	6.70	0.20	8.20
300	6.9	24.6	5.8	--	130.	80.	2.6	0.11	0.01	0.0	1.30	6.70	0.20	8.20

Test No. 12

Wastewater Feed 3.0 US gpm
Residence Time 20.0
Coagulant 1

O_2 Flow Rate 11.6 l/min.
Q 35.0 ppm

O_3 Fed 13.9 g/hr
O_3 Used 20.4 mg/l
O_3 Consumed 19.4 mg/l

CODE	pH	DISS. O_2	DISS. O_3	RES. O_3	TOD	BOD	SS	TOTAL PO_4	ORTHO PO_4	NO_2	NO_3	AMM	ORG N	TOTAL N
100	7.2	0.0	0.0	--	295.	200.	75.0	3.60	0.80	0.0	0.09	7.60	3.20	10.89
200	5.9	2.0	0.0	--	160.	100.	7.8	0.40	0.0	0.10	0.12	7.40	1.20	8.73
210	6.1	17.2	3.3	0.7	145.	92.	11.1	--	--	--	--	--	--	--
220	6.8	20.0	4.5	1.7	135.	86.	12.3	--	--	--	--	--	--	--
230	6.8	20.2	5.5	0.7	125.	82.	13.0	--	--	--	--	--	--	--
240	7.1	27.5	6.6	0.9	120.	78.	15.1	0.40	0.0	0.0	1.16	6.20	0.40	7.76
300	7.1	25.3	5.0	--	110.	72.	9.2	0.30	0.0	0.0	1.16	6.20	0.40	7.76

Test No. 13

Wastewater Feed 3.0 US gpm
Residence Time 20.0
Coagulant 1

O_2 Flow Rate 12.6 l/min.
Q 35.0 ppm

O_3 Fed 18.5 g/hr
O_3 Used 27.2 mg/l
O_3 Consumed 23.3 mg/l

CODE	pH	DISS. O_2	DISS. O_3	RES. O_3	TOD	BOD	SS	TOTAL PO_4	ORTHO PO_4	NO_2	NO_3	AMM	ORG N	TOTAL N
100	7.2	0.0	0.0	--	295.	200.	75.0	3.60	0.80	0.0	0.09	7.60	3.20	10.89
200	5.9	2.4	0.0	--	160.	100.	14.0	0.40	0.0	0.01	0.12	7.40	1.20	8.73
210	6.3	25.2	4.0	0.7	150.	92.	16.4	--	--	--	--	--	--	--
220	6.7	27.0	6.8	0.5	130.	85.	16.0	--	--	--	--	--	--	--
230	6.8	27.7	7.0	3.0	120.	80.	16.7	--	--	--	--	--	--	--
240	7.2	28.6	7.1	9.6	110.	75.	27.0	0.40	0.0	0.0	1.20	6.20	0.30	7.70
300	7.1	25.4	5.8	--	100.	68.	7.8	0.20	0.0	0.0	1.20	6.20	0.30	7.70

Test No. 14

Wastewater Feed 3.0 US gpm
Residence Time 20.0
Coagulant 1

O_2 Flow Rate 14.0 l/min.
Q 35.0 ppm

O_3 Fed 26.3 g/hr
O_3 Used 38.6 mg/l
O_3 Consumed 25.4 mg/l

CODE	pH	DISS. O_2	DISS. O_3	RES. O_3	TOD	BOD	SS	TOTAL PO_4	ORTHO PO_4	NO_2	NO_3	AMM	ORG N	TOTAL N
100	7.2	0.0	0.0	--	295.	200.	75.0	3.60	0.80	0.0	0.09	7.60	3.20	10.89
200	5.9	2.2	0.0	--	160.	100.	9.3	0.40	0.0	0.10	0.12	7.40	1.20	8.73
210	6.7	28.0	6.0	0.8	145.	92.	14.1	--	--	--	--	--	--	--
220	6.8	28.0	7.0	14.0	125.	84.	15.6	--	--	--	--	--	--	--
230	6.8	30.5	6.8	13.8	115.	78.	20.0	--	--	--	--	--	--	--
240	7.0	32.2	7.1	14.1	105.	72.	35.1	0.40	0.0	0.0	1.45	5.90	0.10	7.45
300	6.9	28.1	6.2	--	95.	64.	2.7	0.15	0.0	0.0	1.45	5.90	0.10	7.45

Test No. 15

Wastewater Feed 3.0 US gpm
Residence Time 20.0
Coagulant 1

O_2 Flow Rate 14.0 l/min.
Q 32.0 ppm

O_3 Fed 26.3 g/hr
O_3 Used 38.6 mg/l
O_3 Consumed 25.4 mg/l

CODE	pH	DISS. O_2	DISS. O_3	RES. O_3	TOD	BOD	SS	TOTAL PO_4	ORTHO PO_4	NO_2	NO_3	AMM	ORG N	TOTAL N
100	7.6	0.0	0.0	--	355.	128.	110.0	6.00	2.20	0.10	0.20	12.20	3.70	16.20
200	6.0	1.2	0.0	--	150.	75.	15.4	0.43	0.15	0.20	0.30	10.90	1.60	13.00
210	6.7	28.0	6.0	0.8	135.	68.	18.2	--	--	--	--	--	--	--
220	6.8	28.4	7.1	14.0	125.	62.	18.6	--	--	--	--	--	--	--
230	7.0	30.5	7.0	13.9	115.	55.	22.2	--	--	--	--	--	--	--
240	7.2	32.1	7.3	14.2	95.	50.	34.5	0.41	0.18	0.20	1.70	8.00	1.20	11.10
300	7.2	24.0	6.5	--	85.	40.	8.5	0.13	0.09	0.17	1.65	6.90	0.80	9.52

Test No. 16

Wastewater Feed 3.0 US gpm
Residence Time 10.0
Coagulant 1

O_2 Flow Rate 14.0 l/min.
Q 32.0 ppm

O_3 Fed 26.3 g/hr
O_3 Used 38.6 mg/l
O_3 Consumed 22.6 mg/l

CODE	pH	DISS. O_2	DISS. O_3	RES. O_3	TOD	BOD	SS	TOTAL PO_4	ORTHO PO_4	NO_2	NO_3	AMM	ORG N	TOTAL N
100	7.6	0.0	0.0	--	355.	128.	110.0	6.00	2.20	0.10	0.20	12.20	3.70	16.20
200	6.0	1.2	0.0	--	150.	75.	15.2	0.43	0.15	0.20	0.30	10.80	1.60	12.90
210	6.7	28.6	7.4	0.7	135.	65.	14.6	--	--	--	--	--	--	--
220	6.7	29.8	8.7	14.0	120.	60.	16.1	--	--	--	--	--	--	--
230	6.8	30.2	8.8	18.5	110.	55.	18.0	--	--	--	--	--	--	--
240	7.0	33.6	8.6	18.6	105.	52.	22.2	0.41	0.16	0.15	1.60	8.20	1.20	11.15
300	7.1	26.0	8.0	--	95.	48.	3.2	0.20	0.12	0.15	1.60	7.70	1.00	10.45

Test No. 17

Wastewater Feed 3.0 US gpm
Residence Time 0.0
Coagulant 1

O_2 Flow Rate 14.0 l/min.
Q 32.0 ppm

O_3 Fed 26.3 g/hr
O_3 Used 38.6 mg/l
O_3 Consumed 19.4 mg/l

CODE	pH	DISS. O_2	DISS. O_3	RES. O_3	TOD	BOD	SS	TOTAL PO_4	ORTHO PO_4	NO_2	NO_3	AMM	ORG N	TOTAL N
100	7.6	0.0	0.0	--	355.	128.	110.0	6.00	2.20	0.10	0.20	12.20	3.70	16.20
200	6.0	1.2	0.0	--	150.	75.	15.4	0.43	0.15	0.20	0.30	10.80	1.60	12.90
210	6.7	29.2	9.1	0.7	130.	68.	15.2	--	--	--	--	--	--	--
220	6.9	29.8	10.8	18.8	125.	62.	15.4	--	--	--	--	--	--	--
230	7.1	32.1	10.6	21.0	115.	60.	19.6	--	--	--	--	--	--	--
240	7.2	34.5	10.9	21.9	110.	55.	19.9	0.41	0.17	0.14	1.40	8.40	1.40	11.34
300	7.2	28.1	9.2	--	105.	50.	4.0	0.28	0.15	0.14	1.40	7.90	1.20	10.64

Test No. 18

Wastewater Feed 3.0 US gpm
Residence Time 0.0
Coagulant 1

O_2 Flow Rate 14.0 l/min.
Q 30.0 ppm

O_3 Fed 26.3 g/hr
O_3 Used 38.6 mg/l
O_3 Consumed 19.6 mg/l

CODE	pH	DISS. O_2	DISS. O_3	RES. O_3	TOD	BOD	SS	TOTAL PO_4	ORTHO PO_4	NO_2	NO_3	AMM	ORG N	TOTAL N
100	7.6	2.1	0.0	--	360.	130.	126.0	8.20	2.80	0.20	0.30	15.50	3.90	19.90
200	6.0	4.3	0.0	--	155.	70.	18.2	0.50	0.20	0.20	0.30	13.90	2.00	16.40
210	6.5	30.6	9.0	0.7	140.	66.	19.1	--	--	--	--	--	--	--
220	6.9	30.8	10.9	17.9	135.	60.	19.1	--	--	--	--	--	--	--
230	7.2	32.4	10.6	21.9	120.	56.	20.9	--	--	--	--	--	--	--
240	7.1	34.3	10.8	21.2	110.	50.	22.4	0.50	0.21	0.10	1.40	11.30	1.80	14.60
300	7.1	28.1	9.2	--	100.	46.	9.2	0.20	0.20	0.10	1.35	10.90	1.40	13.75

Test No. 19

Wastewater Feed 3.0 US gpm
Residence Time 10.0
Coagulant 1

O_2 Flow Rate 14.0 l/min.
Q 30.0 ppm

O_3 Fed 26.3 g/hr
O_3 Used 38.6 mg/l
O_3 Consumed 22.7 mg/l

CODE	pH	DISS. O_2	DISS. O_3	RES. O_3	TOD	BOD	SS	TOTAL PO_4	ORTHO PO_4	NO_2	NO_3	AMM	ORG N	TOTAL N
100	7.6	2.1	0.0	--	360.	130.	126.0	8.20	2.80	0.20	0.30	15.50	3.90	19.90
200	6.0	4.3	0.0	--	155.	70.	18.4	0.52	0.20	0.20	0.30	13.80	1.90	16.30
210	6.7	28.2	7.5	0.8	135.	66.	19.1	--	--	--	--	--	--	--
220	6.9	29.6	8.6	13.9	125.	52.	19.7	--	--	--	--	--	--	--
230	7.4	30.5	8.9	17.9	115.	48.	21.2	--	--	--	--	--	--	--
240	7.3	33.4	8.7	18.9	100.	45.	23.6	0.50	0.20	0.10	1.50	10.90	1.60	14.10
300	7.3	25.8	8.0	--	95.	36.	12.4	0.27	0.10	0.10	1.50	9.80	1.40	12.80

Test No. 20

Wastewater Feed 3.0 US gpm
Residence Time 20.0
Coagulant 1

O_2 Flow Rate 14.0 l/min.
Q 30.0 ppm

O_3 Fed 26.3 g/hr
O_3 Used 38.6 mg/l
O_3 Consumed 25.5 mg/l

CODE	pH	DISS. O_2	DISS. O_3	RES. O_3	TOD	BOD	SS	TOTAL PO_4	ORTHO PO_4	NO_2	NO_3	AMM	ORG N	TOTAL N
100	7.6	2.1	0.0	--	360.	130.	126.0	8.20	2.80	0.20	0.30	15.50	3.90	19.90
200	5.9	4.3	0.0	--	155.	70.	18.2	0.50	0.20	0.20	0.30	13.90	1.90	16.30
210	6.5	28.0	6.1	0.8	135.	64.	23.1	--	--	--	--	--	--	--
220	6.7	28.2	7.0	14.0	120.	52.	25.2	--	--	--	--	--	--	--
230	7.1	30.5	7.4	13.9	100.	44.	25.1	--	--	--	--	--	3.00	--
240	7.3	32.2	7.3	13.9	95.	40.	26.0	0.40	0.20	0.10	1.70	10.90	1.20	13.90
300	7.3	24.2	6.2	--	85.	34.	10.0	0.15	0.10	0.10	1.60	9.70	0.80	12.20

Test No. 21

Wastewater Feed 3.0 US gpm
Residence Time 40.0
Coagulant 1

O_2 Flow Rate 14.0 l/min.
Q^2 30.0 ppm

O_3 Fed 26.3 g/hr
O_3 Used 38.6 mg/l
C_3 Consumed 21.3 mg/l

CODE	pH	DISS. O_2	DISS. O_3	RES. O_3	TOD	BOD	SS	TOTAL PO_4	ORTHO PO_4	NO_2	NO_3	AMM	ORG N	TOTAL N
100	--	1.0	0.0	--	265.	--	--	--	--	--	--	--	--	--
200	--	5.4	0.0	--	150.	--	--	--	--	--	--	--	--	--
212	--	24.0	10.8	--	130.	--	--	--	--	--	--	--	--	--
211	--	25.1	7.0	--	125.	--	--	--	--	--	--	--	--	--
210	--	24.8	4.0	10.8	130.	--	--	--	--	--	--	--	--	--
222	--	31.0	11.0	--	110.	--	--	--	--	--	--	--	--	--
221	--	29.2	6.9	--	110.	--	--	--	--	--	--	--	--	--
220	--	32.8	4.2	17.2	105.	--	--	--	--	--	--	--	--	--
300	--	22.8	2.9	--	90.	--	--	--	--	--	--	--	--	--

Test No. 22

Wastewater Feed 3.0 US gpm
Residence Time 20.0
Coagulant 1

O_2 Flow Rate 14.0 l/min.
Q^2 30.0 ppm

O_3 Fed 26.3 g/hr
O_3 Used 38.6 mg/l
O_3 Consumed 18.8 mg/l

CODE	pH	DISS. O_2	DISS. O_3	RES. O_3	TOD	BOD	SS	TOTAL PO_4	ORTHO PO_4	NO_2	NO_3	AMM	ORG N	TOTAL N
100	--	1.0	0.0	--	265.	--	--	--	--	--	--	--	--	--
200	--	5.5	0.0	--	150.	--	--	--	--	--	--	--	--	--
212	--	24.0	10.5	--	130.	--	--	--	--	--	--	--	--	--
210	--	24.5	6.8	10.9	130.	--	--	--	--	--	--	--	--	--
222	--	29.6	10.5	--	115.	--	--	--	--	--	--	--	--	--
220	--	28.4	6.8	21.2	110.	--	--	--	--	--	--	--	--	--
300	--	20.0	6.3	--	95.	--	--	--	--	--	--	--	--	--

Test No. 23

Wastewater Feed 3.0 US gpm
Residence Time 0.0
Coagulant 1

O_2 Flow Rate 14.0 l/min.
Q^2 30.0 ppm

O_3 Fed 26.3 g/hr
O_3 Used 38.6 mg/l
O_3 Consumed 16.4 mg/l

CODE	pH	DISS. O_2	DISS. O_3	RES. O_3	TOD	BOD	SS	TOTAL PO_4	ORTHO PO_4	NO_2	NO_3	AMM	ORG N	TOTAL N
100	--	1.0	0.0	--	265.	--	--	--	--	--	--	--	--	--
200	--	5.5	0.0	--	150.	--	--	--	--	--	--	--	--	--
210	--	24.2	10.5	11.0	130.	--	--	--	--	--	--	--	--	--
220	--	27.2	10.8	25.0	120.	--	--	--	--	--	--	--	--	--
300	--	21.0	8.5	--	110.	--	--	--	--	--	--	--	--	--

Test No. 24

Wastewater Feed 3.0 US gpm
Residence Time 0.0
Coagulant 1

O_2 Flow Rate 14.0 l/min.
Q^2 32.0 ppm

O_3 Fed 26.3 g/hr
O_3 Used 38.6 mg/l
O_3 Consumed 16.5 mg/l

CODE	pH	DISS. O_3	DISS. O_3	RES. O_3	TOD	BOD	SS	TOTAL PO_4	ORTHO PO_4	NO_2	NO_3	AMM	ORG N	TOTAL N
100	--	2.0	0.0	--	175.	--	--	--	--	--	--	--	--	--
200	--	4.2	0.0	--	77.	--	--	--	--	--	--	--	--	--
210	--	23.9	10.8	10.8	64.	--	--	--	--	--	--	--	--	--
220	--	30.2	11.4	25.0	52.	--	--	--	--	--	--	--	--	--
300	--	20.2	8.7	--	48.	--	--	--	--	--	--	--	--	--

Test No. 25

Wastewater Feed 3.0 US gpm
Residence Time 20.0
Coagulant 1

O_2 Flow Rate 14.0 l/min.
Q 32.0 ppm

O_3 Fed 26.3 g/hr
O_3 Used 38.6 mg/l
O_3 Consumed 18.9 mg/l

CODE	pH	DISS. O_2	DISS. O_3	RES. O_3	TOD	BOD	SS	TOTAL PO_4	ORTHO PO_4	NO_2	NO_3	AMM	ORG N	TOTAL N
100	--	2.0	0.0	--	175.	--	--	--	--	--	--	--	--	--
200	--	4.2	0.0	--	78.	--	--	--	--	--	--	--	--	--
212	--	16.3	10.8	--	60.	--	--	--	--	--	--	--	--	--
210	--	16.6	7.4	11.1	60.	--	--	--	--	--	--	--	--	--
222	--	20.0	11.1	--	46.	--	--	--	--	--	--	--	--	--
220	--	20.2	7.6	20.8	45.	--	--	--	--	--	--	--	--	--
300	--	13.8	5.7	--	40.	--	--	--	--	--	--	--	--	--

Test No. 26

Wastewater Feed 3.0 US gpm
Residence Time 40.0
Coagulant 1

O_2 Flow Rate 14.0 l/min.
Q 32.0 ppm

O_3 Fed 26.3 g/hr
O_3 Used 38.6 mg/l
O_3 Consumed 21.4 mg/l

CODE	pH	DISS. O_2	DISS. O_3	RES. O_3	TOD	BOD	SS	TOTAL PO_4	ORTHO PO_4	NO_2	NO_3	AMM	ORG N	TOTAL N
100	--	2.0	0.0	--	175.	--	--	--	--	--	--	--	--	--
200	--	4.2	0.0	--	78.	--	--	--	--	--	--	--	--	--
212	--	21.0	10.8	--	60.	--	--	--	--	--	--	--	--	--
211	--	20.0	7.2	--	62.	--	--	--	--	--	--	--	--	--
210	--	21.0	4.5	10.5	62.	--	--	--	--	--	--	--	--	--
222	--	23.0	11.0	--	39.	--	--	--	--	--	--	--	--	--
221	--	23.0	7.3	--	39.	--	--	--	--	--	--	--	--	--
220	--	23.4	4.6	17.4	37.	--	--	--	--	--	--	--	--	--
300	--	16.1	4.1	--	32.	--	--	--	--	--	--	--	--	--

Test No. 27

Wastewater Feed 3.0 US gpm
Residence Time 20.0
Coagulant 2

O_2 Flow Rate 14.0 l/min.
Q 10.0 ppm

O_3 Fed 26.3 g/hr
O_3 Used 38.6 mg/l
O_3 Consumed 25.4 mg/l

CODE	pH	DISS. O_2	DISS. O_3	RES. O_3	TOD	BOD	SS	TOTAL PO_4	ORTHO PO_4	NO_2	NO_3	AMM	ORG N	TOTAL N
100	7.2	0.0	0.0	--	285.	200.	66.0	4.00	1.05	0.38	0.10	27.10	1.90	29.48
200	9.5	2.4	0.0	--	145.	105.	30.4	1.70	0.52	0.42	0.10	22.40	1.60	24.52
210	8.1	27.4	6.4	0.5	130.	95.	31.0	--	--	--	--	--	--	--
220	8.0	26.4	6.7	14.1	115.	89.	30.1	--	--	--	--	--	--	--
230	7.8	30.0	6.5	13.9	95.	80.	36.8	--	--	--	--	--	--	--
240	7.6	29.4	6.6	14.2	90.	73.	37.1	1.60	0.35	0.15	3.10	14.20	0.90	18.35
300	7.6	24.0	5.8	--	80.	65.	5.5	0.70	0.10	0.15	3.10	13.80	0.90	17.95

Test No. 28

Wastewater Feed 3.0 US gpm
Residence Time 20.0
Coagulant 2

O_2 Flow Rate 12.6 l/min.
Q 10.0 ppm

O_3 Fed 18.5 g/hr
O_3 Used 27.2 mg/l
O_3 Consumed 23.3 mg/l

CODE	pH	DISS. O_2	DISS. O_3	RES. O_3	TOD	BOD	SS	TOTAL PO_4	ORTHO PO_4	NO_2	NO_3	AMM	ORG N	TOTAL N
100	7.2	0.0	0.0	--	285.	200.	66.0	4.00	1.05	0.38	0.10	27.10	1.90	29.48
200	9.5	2.4	0.0	--	145.	104.	30.4	1.70	0.52	0.42	0.10	22.40	1.60	24.52
210	9.0	25.8	3.8	0.7	130.	96.	31.0	--	--	--	--	--	--	--
220	8.4	28.8	6.8	0.7	115.	90.	32.4	--	--	--	--	--	--	--
230	7.8	30.2	6.6	3.0	105.	84.	33.0	--	--	--	--	--	--	--
240	7.7	32.6	7.3	9.5	95.	78.	37.6	1.60	0.50	0.30	2.90	14.50	1.00	18.70
300	7.7	24.2	5.5	--	90.	72.	4.7	0.70	0.12	0.27	2.90	14.00	1.00	18.17

Test No. 29

Wastewater Feed 3.0 US gpm
Residence Time 20.0
Coagulant 2

O_2 Flow Rate 11.6 l/min
Q 10.0 ppm

O_3 Fed 13.9 g/hr
O_3 Used 20.4 mg/l
O_3 Consumed 19.8 mg/l

CODE	pH	DISS. O_2	DISS. O_3	RES. O_3	TOD	BOD	SS	TOTAL PO_4	ORTHO PO_4	NO_2	NC_3	AMM	ORG N	TOTAL N
100	7.2	0.0	0.0	--	285.	200.	66.0	4.00	1.05	0.38	0.10	27.10	1.90	29.48
200	9.5	2.4	0.0	--	145.	104.	19.1	0.52	1.70	0.42	0.10	22.40	1.60	24.52
210	8.7	22.6	2.8	0.7	135.	98.	19.6	--	--	--	--	--	--	--
220	8.5	23.4	4.3	0.4	120.	94.	19.0	--	--	--	--	--	--	--
230	8.1	23.6	5.1	0.3	115.	86.	20.0	--	--	--	--	--	--	--
240	8.0	27.0	5.8	0.8	105.	82.	21.4	0.50	1.60	0.20	2.40	15.00	1.10	18.70
300	8.0	25.6	5.4	--	95.	78.	3.8	0.17	0.90	0.20	2.40	14.70	1.10	18.40

Test No. 30

Wastewater Feed 3.0 US gpm
Residence Time 40.0
Coagulant 2

O_2 Flow Rate 14.0 l/min
Q 10.0 ppm

O_3 Fed 26.3 g/hr
O_3 Used 38.6 mg/l
O_3 Consumed 21.5 mg/l

CODE	PH	DISS. O_2	DISS. O_3	RES. O_3	TOD	BOD	SS	TOTAL PO_4	ORTHO PO_4	NO_2	NO_3	AMM	ORG N	TOTAL N
100	8.1	0.0	0.0	--	360.	200.	68.0	6.10	1.45	0.08	0.10	18.70	2.00	20.88
200	9.5	1.5	0.0	--	270.	120.	30.0	1.75	0.50	0.10	0.10	16.40	1.80	18.40
212	8.1	25.5	11.0	--	245.	104.	31.3	--	--	--	--	--	--	--
211	8.1	25.6	6.8	--	240.	106.	32.1	--	--	--	--	--	--	--
210	8.0	25.7	3.2	10.8	240.	104.	32.0	--	--	--	--	--	--	--
222	7.6	29.2	10.8	--	215.	90.	41.4	--	--	--	--	--	--	--
221	7.5	29.1	6.7	--	215.	90.	40.0	--	--	--	--	--	--	--
220	7.5	28.9	3.9	17.0	210.	88.	40.0	1.45	0.40	0.0	3.10	12.50	0.50	16.10
300	7.5	24.2	2.9	--	190.	72.	20.6	0.35	0.05	0.0	3.20	11.60	0.40	14.70

Test No. 31

Wastewater Feed 3.0 US gpm
Residence Time 20.0
Coagulant 2

O_2 low Rate 14.0 l/min.
Q 10.0 ppm

O_3 Fed .6.3 g/hr
O_3 Used 38.6 mg/l
O_3 Consumed 19.1 mg/l

CODE	pH	DISS. O_2	DISS. O_3	RES. O_3	TOD	BOD	SS	TOTAL PO_4	ORTHO PO_4	NO_2	NO_3	AMM	ORG N	TOTAL N
100	8.1	0.0	0.0	--	360.	200.	68.0	6.10	1.45	0.08	0.10	18.70	2.00	20.88
200	9.5	1.8	0.0	--	270.	120.	24.0	1.75	0.50	0.10	0.10	16.40	1.80	18.40
212	8.2	25.5	11.0	--	245.	104.	25.1	--	--	--	--	--	--	--
210	8.3	25.6	6.8	10.8	250.	106.	25.1	--	--	--	--	--	--	--
222	7.8	29.2	10.8	--	220.	96.	27.2	--	--	--	--	--	--	--
220	7.8	29.1	6.7	20.9	225.	94.	28.4	1.50	0.40	0.05	2.90	12.50	0.60	16.05
300	7.8	23.5	6.1	--	210.	86.	12.0	0.40	0.15	0.05	2.90	11.50	0.60	15.05

Test No. 32

Wastewater Feed 3.0 US gpm
Residence Time 0.0
Coagulant 2

O_2 Flow Rate 14.0 l/min.
Q 10.0 ppm

O_3 Fed 26.3 g/hr
O_3 Used 38.6 mg/l
O_3 Consumed 16.7 mg/l

CODE	PH	DISS. O_2	DISS. O_3	RES. O_3	TOD	BOD	SS	TOTAL PO_4	ORTHO PO_4	NO_2	NO_3	AMM	ORG N	TOTAL N
100	8.1	0.0	0.0	--	360.	200.	68.0	6.10	1.45	0.08	0.10	18.70	2.00	20.88
200	9.5	1.6	0.0	--	270.	120.	29.2	1.75	0.50	0.10	0.10	16.40	1.80	18.40
210	8.3	24.2	10.8	10.9	235.	102.	34.8	--	--	--	--	--	--	--
220	7.9	28.6	10.9	24.6	230.	95.	34.7	1.50	0.45	0.05	2.70	12.90	0.60	16.25
300	7.9	25.1	9.4	--	220.	88.	7.3	0.95	0.25	0.06	2.80	12.00	0.70	15.56

Test No. 33

Wastewater Feed 5.0 US gpm
Residence Time 12.0
Coagulant 2

O_2 Flow Rate 14.0 l/min.
Q^2 10.0 ppm

O_3 Fed 26.3 g/hr
O_3 Used 23.2 mg/l
O_3 Consumed 19.6 mg/l

CODE	pH	DISS. O_2	DISS. O_3	RES. O_3	TOD	BOD	SS	TOTAL PO_4	ORTHO PO_4	NO_2	NO_3	AMM	ORG N	TOTAL N
100	7.8	0.0	0.0	--	410.	240.	120.0	6.30	1.80	0.10	0.30	15.40	4.00	19.80
200	9.5	2.8	0.0	--	190.	110.	35.2	1.80	0.20	0.10	0.30	13.90	2.00	16.30
210	9.0	28.0	4.4	0.5	170.	104.	36.4	--	--	--	--	--	--	--
220	8.7	28.1	7.0	0.8	165.	96.	38.2	--	--	--	--	--	--	--
230	8.6	28.1	8.0	3.1	155.	90.	41.4	--	--	--	--	--	--	--
240	8.4	28.3	8.1	14.9	145.	86.	44.1	1.80	0.20	0.0	2.30	9.50	1.10	2.00 12.90
300	8.4	25.9	6.2	--	135.	78.	20.1	1.10	0.10	0.0	2.30	9.40	1.00	12.70

Test No. 34

Wastewater Feed 3.0 US gpm
Residence Time 20.0
Coagulant 2

O_2 Flow Rate 14.0 l/min.
Q^2 10.0 ppm

O_3 Fed 26.3 g/hr
O_3 Used 38.6 mg/l
O_3 Consumed 25.6 mg/l

CODE	pH	DISS. O_2	DISS. O_3	RES. O_3	TOD	BOD	SS	TOTAL PO_4	ORTHO PO_4	NO_2	NO_3	AMM	ORG N	TOTAL N
100	7.8	0.0	0.0	--	410.	240.	120.0	6.30	1.80	0.10	0.30	15.40	4.00	19.80
200	9.5	2.9	0.0	--	190.	110.	25.1	1.80	0.20	0.10	0.30	13.90	2.00	16.30
210	9.0	27.1	6.1	0.5	175.	102.	29.3	--	--	--	--	--	--	--
220	8.6	28.3	6.7	13.9	160.	95.	31.7	--	--	--	--	--	--	--
230	8.2	33.1	6.5	13.9	145.	90.	34.9	--	--	--	--	--	--	--
240	8.0	33.3	6.6	13.8	135.	80.	37.9	1.80	0.20	0.0	2.70	8.20	0.90	11.80
300	8.0	26.9	5.8	--	125.	70.	16.4	1.00	0.10	0.0	2.70	8.20	0.90	11.80

Test No. 35

Wastewater Feed 2.0 US gpm
Residence Time 30.0
Coagulant 2

O_2 Flow Rate 14.0 l/min
Q^2 10.0 ppm

O_3 Fed 26.3 g/hr
O_3 Used 57.9 mg/l
O_3 Consumed 33.2 mg/l

CODE	pH	DISS. O_2	DISS. O_3	RES. O_3	TOD	BOD	SS	TOTAL PO_4	ORTHO PO_4	NO_2	NO_3	AMM	ORG N	TOTAL N
100	7.8	0.0	0.0	--	410.	240.	120.0	6.30	1.80	0.10	0.30	15.40	4.00	19.80
200	9.5	2.8	0.0	--	190.	110.	23.1	1.80	0.20	0.10	0.30	13.90	2.00	16.30
210	9.0	28.7	5.2	6.7	170.	100.	26.1	--	--	--	--	--	--	--
220	8.4	33.1	5.1	15.6	150.	88.	29.4	--	--	--	--	--	--	--
230	8.0	33.2	5.2	15.6	130.	78.	34.8	--	--	--	--	--	--	--
240	7.8	33.4	5.1	15.6	115.	70.	36.1	1.80	0.20	0.0	2.90	7.80	0.90	11.60
300	7.8	28.4	4.1	--	110.	60.	12.1	0.40	0.10	0.0	2.90	7.70	0.80	11.40

Test No. 36

Wastewater Feed 3.0 US gpm
Residence Time 20.0
Coagulant 2

O_2 Flow Rate 16.0 l/min.
Q^2 30.0 ppm

O_3 Fed 0.0 g/hr
O_3 Used
O_3 Consumed

CODE	pH	DISS. O_2	DISS. O_3	RES. O_3	TOD	BOD	SS	TOTAL PO_4	ORTHO PO_4	NO_2	NO_3	AMM	ORG N	TOTAL N
100	7.4	0.0	0.0	--	420.	290.	135.0	17.20	1.10	0.0	0.05	15.60	2.40	18.05
200	9.5	1.7	0.0	--	130.	68.	17.5	4.50	0.20	0.0	0.10	13.50	1.70	15.30
210	9.2	1.5	0.0	--	130.	68.	17.9	--	--	--	--	--	--	--
220	9.1	1.5	0.0	--	130.	68.	16.8	--	--	--	--	--	--	--
230	9.0	1.5	0.0	--	130.	68.	18.1	--	--	--	--	--	--	--
240	9.0	1.5	0.0	--	130.	68.	17.5	4.40	0.20	0.01	0.10	8.90	1.70	10.71
300	9.0	1.5	0.0	--	120.	60.	8.6	3.70	0.20	0.01	0.10	8.80	1.50	10.41

Test No. 37

Wastewater Feed 3.0 US gpm
Residence Time 20.0
Coagulant 2

O_2 Flow Rate 14.0 l/min
Q 30.0 ppm

O_3 Fed 0.0 g/hr
O_3 Used
O_3 Consumed

CODE	pH	DISS. O_2	DISS. O_3	RES. O_3	TOD	BOD	SS	TOTAL PO_4	ORTHO PO_4	NO_2	NC_3	AMM	ORG N	TOTAL N
100	7.4	0.0	0.0	--	420.	290.	135.0	17.20	1.10	0.0	0.05	15.60	2.40	18.05
200	9.5	1.5	0.0	--	130.	68.	17.7	4.50	0.20	0.0	0.10	13.50	1.70	15.30
210	9.1	12.3	0.0	--	120.	64.	17.1	--	--	--	--	--	--	--
220	9.0	12.3	0.0	--	120.	64.	17.9	--	--	--	--	--	--	--
230	8.9	12.7	0.0	--	120.	64.	17.4	--	--	--	--	--	--	--
240	9.0	12.8	0.0	--	120.	64.	18.1	4.50	0.20	0.0	0.20	8.50	1.70	10.40
300	8.8	10.4	0.0	--	115.	55.	5.8	3.60	0.20	0.0	0.15	8.50	1.40	10.05

Test No. 38

Wastewater Feed 3.0 US gpm
Residence Time 20.0
Coagulant 2

O_2 Flow Rate 14.0 l/min.
Q 30.0 ppm

O_3 Fed 26.3 g/hr
O_3 Used 38.6 mg/l
O_3 Consumed 25.7 mg/l

CODE	pH	DISS. O_2	DISS. O_3	RES. O_3	TOD	BOD	SS	TOTAL PO_4	ORTHO PO_4	NO_2	NO_3	AMM	ORG N	TOTAL N
100	7.4	0.0	0.0	--	420.	290.	135.0	17.20	1.10	0.0	0.0	15.60	2.40	18.00
200	9.5	1.5	0.0	--	130.	68.	17.0	4.50	0.20	0.0	0.0	13.50	1.70	15.20
210	9.0	22.1	6.1	0.4	110.	62.	19.1	--	--	--	--	--	--	--
220	8.5	26.1	6.6	13.7	95.	56.	20.4	--	--	--	--	--	--	--
230	8.4	25.9	6.7	14.0	85.	48.	25.1	--	--	--	--	--	--	--
240	8.0	26.0	6.6	13.8	75.	44.	27.4	4.30	0.20	0.0	1.40	7.30	0.90	9.60
300	7.9	20.0	5.7	--	65.	38.	5.2	1.90	0.05	0.01	1.30	7.20	0.70	9.21

Test No. 39

Wastewater Feed 3.0 US gpm
Residence Time 0.0
Coagulant 2

O_2 Flow Rate 14.0 l/min.
Q 30.0 ppm

O_3 Fed 26.3 g/hr
O_3 Used 38.6 mg/l
O_3 Consumed 20.0 mg/l

CODE	pH	DISS. O_2	DISS. O_3	RES. O_3	TOD	BOD	SS	TOTAL PO_4	ORTHO PO_4	NO_2	NO_3	AMM	ORG N	TOTAL N
100	7.3	2.0	0.0	--	275.	190.	96.0	13.00	2.40	0.0	0.10	16.10	2.90	19.10
200	9.5	3.5	0.0	--	120.	62.	7.6	1.70	0.10	0.05	0.30	13.90	1.60	15.85
210	8.6	26.0	8.6	0.4	110.	58.	8.1	--	--	--	--	--	--	--
220	8.4	31.4	11.0	17.9	100.	54.	8.8	--	--	--	--	--	--	--
230	8.3	31.5	10.8	21.0	90.	52.	9.2	--	--	--	--	--	--	--
240	8.1	32.1	11.0	21.0	80.	48.	14.0	1.60	0.10	0.02	1.30	9.40	0.90	11.62
300	8.1	24.1	9.2	--	75.	42.	6.0	0.90	0.05	0.02	1.30	9.30	0.70	11.32

Test No. 40

Wastewater Feed 3.0 US gpm
Residence Time 10.0
Coagulant 2

O_2 Flow Rate 14.0 l/min.
Q 30.0 ppm

O_3 Fed 26.3 g/hr
O_3 Used 38.6 mg/l
O_3 Consumed 23.0 mg/l

CODE	pH	DISS. O_2	DISS. O_3	RES. O_3	TOD	BOD	SS	TOTAL PO_4	ORTHO PO_4	NO_2	NO_3	AMM	ORG N	TOTAL N
100	7.3	2.0	0.0	--	275.	190.	96.0	13.00	2.40	0.0	0.10	16.10	2.90	19.10
200	9.5	3.5	0.0	--	120.	62.	7.6	1.70	0.10	0.05	0.30	13.90	1.60	15.85
210	8.6	25.4	7.4	0.6	110.	54.	8.3	--	--	--	--	--	--	--
220	8.4	29.4	8.4	13.9	95.	50.	8.9	--	--	--	--	--	--	--
230	8.1	29.3	8.8	17.9	85.	46.	10.1	--	--	--	--	--	--	--
240	7.9	29.7	8.6	18.1	75.	44.	14.8	1.70	0.10	0.02	1.60	9.20	0.80	11.62
300	7.9	23.2	6.0	--	68.	40.	6.2	1.00	0.10	0.02	1.60	9.20	0.70	11.52

Test No. 41

Wastewater Feed 3.0 US gpm
Residence Time 20.0
Coagulant 2

O_2 Flow Rate 14.0 l/min.
Q 30.0 ppm

O_3 Fed 26.3 g/hr
O_3 Used 38.6 mg/l
O_3 Consumed 25.7 mg/l

CODE	pH	DISS. O_2	DISS. O_3	RES. O_3	TOD	BOD	SS	TOTAL PO_4	ORTHO PO_4	NO_2	NO_3	AMM	ORG N	TOTAL N
100	7.3	2.0	0.0	--	275.	190.	96.0	13.00	2.40	0.0	0.10	16.10	2.90	19.10
200	9.5	3.5	0.0	--	120.	62.	7.6	1.70	0.10	0.05	0.30	13.90	1.60	15.85
210	8.7	24.1	6.2	0.4	105.	56.	8.3	--	--	--	--	--	--	--
220	8.4	26.3	6.7	13.8	90.	50.	8.9	--	--	--	--	--	--	--
230	8.0	26.5	6.6	13.9	75.	44.	11.4	--	--	--	--	--	--	--
240	7.8	27.1	6.7	13.8	70.	40.	16.5	1.70	0.05	0.01	1.90	8.80	0.60	11.31
300	7.8	21.2	6.2	--	60.	35.	2.0	0.05	0.90	0.01	1.90	8.60	0.60	11.11

Test No. 42

Wastewater Feed 3.0 US gpm
Residence Time 20.0
Coagulant 0

O_2 Flow Rate 14.0 l/min.
Q 0.0

O_3 Fed 26.3 g/hr
O_3 Used 38.6 mg/l
O_3 Consumed 25.3 mg/l

CODE	pH	DISS. O_2	DISS. O_3	RES. O_3	TOD	BOD	SS	TOTAL PO_4	ORTHO PO_4	NO_2	NO_3	AMM	ORG N	TOTAL N
200	7.8	16.1	0.4	-	60	35	4.8	0.90	0.05	0.02	1.90	8.60	0.60	11.12
210	7.8	26.4	6.5	0.4	55	32	5.0	-	-	-	-	-	-	-
220	7.6	26.7	7.3	14.0	50	29	5.0	-	-	-	-	-	-	-
230	7.5	27.1	7.2	14.3	45	27	5.4	-	-	-	-	-	-	-
240	7.5	27.4	7.2	14.3	40	22	6.1	0.90	0.05	0.01	2.90	5.20	0.40	8.51
300	7.4	20.9	6.2	-	35	16	1.2	0.40	0.05	0.01	2.90	5.10	0.30	8.31

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